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BY

CAPTAIN D. McCAY, M.B., B.CH., B.A.O., I.M.S.
Professor of Physiology, Medical College, Calcutta

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Price annas 12 or 1s.

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1908

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STANDARDS OF THE CONSTITUENTS OF THE URINE AND BLOOD—AND THE BEARING OF THE METABOLISM OF BENGALIS ON THE PROBLEMS OF NUTRITION.

THE work recorded in this paper was begun in July 1906 and has been carried on in the Physiological Laboratories of the Medical College, Calcutta.[1] Chittenden's investigations and writings have tended to upset the old-established views on standard dietaries and on the quantities of the different proximate principles necessary for the maintenance of health and vigour, and have, at the same time, placed the metabolism of the most important of the food-stuffs—proteids—on an absolutely different footing. His brilliant researches on the problems of nutrition have stimulated students of physiology all the world over and were indeed the exciting cause of the present investigations.

The Bengali is, in a very great degree, a vegetarian, living mainly on rice and *dhall* (pulse); it was therefore very probable that the diet of the Bengali would be found deficient in proteid compared with ordinary standard diets, and would approach fairly closely to the type considered amply sufficient by Chittenden. This opinion was early forced on us by the results obtained from a study of the urine of the Bengali, which was undertaken as a matter of urgent clinical importance in order to get reliable standards of the excretion of the different constituents.

It was very soon evident that the ordinary standards of excretion of the urinary constituents for Europeans, as stated in physiological text-books, could not be accepted for natives of Bengal and that therefore any deductions of a clinical or practical nature based on a comparison with those standards must be misleading.

The first part of this paper will deal with standards of the different constituents found in the urine of Bengalis. These have been obtained from a large series of observations on several different classes of the native population. The present publication will take into account only the more important constituents —those, namely, of clinical rather than of scientific importance; the other more

(1) In the actual experimental and analytical investigations the whole staff of the physiological department was actively engaged for over a year, and it is due to the very able, loyal and willing help of my assistants that the publication of these researches is rendered possible. I desire at once to acknowledge my indebtedness to my fellow-workers and to secure for them a full share in whatever credit the facts and figures herein recorded may be considered worthy of. The names of those who assisted are :—

Assistant Surgeon S. C. Banerji, L.M.S., Assistant Professor of Physiology.

" " L. M. Ghoshal, L.M.S., and " " M. M. Dutta, L.M.S., } Demonstrators, Physiological Department, Medical College, Calcutta.

minute details will be dealt with subsequently, the work on them not being at present complete.

Further, as no consideration of the urine in itself could be looked on as a statement of the whole case, without, at the same time, a review of the condition of the blood from which the urine is derived, it will be necessary to make some attempt to examine the modifications met with in the constituents of the blood in natives of Bengal.

The modifications of the blood and urine found during these investigations naturally led to the question of the causation of the changes ; a series of investigations, therefore, was carried out—in which the intake and output were carefully estimated—to gain some insight into the metabolism of the Bengali. The second part of the paper will be devoted to an analysis of the results obtained from these observations and to other evidence on the sufficiency, or otherwise, of certain diet standards.

Part I.—The Urine and Blood of the Bengali.

A. The Urine.

In carrying out this investigation the procedure throughout was as follows :—The urine passed in each twenty-four hours was collected for four or five consecutive days. The subjects of the experiments were students attending the physiological department and servants of the college of different castes and, therefore, living on more or less different classes of food-stuffs. The students and qualified assistants were first examined, and our thanks are due to them for the loyal way in which in every instance they carried out the collection of the urine and for the interest they took in the investigation.

These two classes, assistants and students, belong to the higher castes and are fairly well-to-do, so that they have a free choice so far as quantity of food is concerned, certain meats—more particularly beef—being forbidden by their religion. Fish, mutton, goat and other forms of flesh-meat, however, are permitted.

The examination of these two groups being completed, the servants of the college were next examined. They include *durwans* or gate-keepers—usually belonging to higher castes; bearers of inferior castes; and lastly *domes* and *mehtars* belonging to the lowest castes.

The importance of the study of the urine of the *domes* is seen in the table of analysis—Table I—these men being of low caste eat anything they can get and are particularly fond of flesh. They purchase the cheaper, almost unsaleable, portions of animals at the slaughter-house and make use of them as food.

By examining the urine of each person daily for four or five consecutive days more accurate results were obtained than if the urine passed during one

day only had been examined. The results shown in Table I are the averages of the figures obtained by the daily analyses.

The different points noted are :—*Caste*—all were Hindus. *Age*—all were of adult age. *Weight*—average weight over a large series is given. *Quantity of Urine*—in cubic centimetres. *Specific Gravity. Urea*—quantity excreted in grammes. *Total Nitrogen*—in grammes. *Freezing-point of Urine. Chlorides*—in grammes.

Table I.

AVERAGE DAILY EXCRETION OF THE CONSTITUENTS OF THE URINE OF BENGALIS.

Each observation is the average of the results obtained by daily analyses on four or five consecutive days.

STUDENTS.

No.	Number of analyses.	Quantity of urine in c.c.	Sp. Gr.	Urea grms.	Total Nitrogen grms.	Freezing-point (Centigrade).	Chlorides grms.
1	5	1217	1016	14·33	6·63	—1·56°	15·54
2	5	700	1019	12·88	5·50	—1·54°	6·72
3	5	1249	1015	14·22	6·85	—1 40°	12·05
4	4	980	1015	13·51	6·55	—1·16°	7·80
5	4	1066	1011	11·85	5·23	—1·18°	9·26
6	5	1480	1016	13·51	6·62	— ·91°	9·86
7	5	982	1022	12·45	6·06	—1·37°	11·14
8	4	926	1011	14·87	7·20	—2·31°	18·04
9	4	1855	1018	15·88	7·77	—1·06°	6·52
10	4	805	1017	9·80	4·50	—1·52°	10·59
11	4	1319	1011	14·60	6·42	—1·45°	16·45
12	5	1461	1011	10·83	5·55	—1·11°	10·11
13	4	895	1017	7·56	3·87	—1·51°	12·04
14	5	1312	1010	10·51	4·50	—1·14°	9·15
15	4	860	1022	13·37	6·21	—2·30°	15·43
16	4	1364	1012	13·08	5·90	—1·35°	12·09
17	4	1227	1012	12·37	5·54	—1·18°	12·23
18	5	1227	1011	10·87	4·91	—·89°	8·48
19	4	667	1021	11·06	5·21	—1·91°	9·30

STUDENTS—*continued.*

No.	Number of analyses.	Quantity of urine in c.c.	Sp. Gr.	Urea grms.	Total Nitrogen grms.	Freezing-point (Centigrade).	Chlorides grms.
20	4	1115	1015	11·30	5·31	—1·48°	11·97
21	5	985	1016	13·04	6·32	—1·46°	11·65
22	5	1634	1014	18·17	9·04	—1·55°	19·39
23	5	1256	1012	11·93	5·27	—1·28°	15·64
24	4	1415	1015	16·42	7·65	—1·38°	14·50
25	5	948	1024	15·67	7·24	—2·40°	18·17
26	4	720	1015	7·79	3·40	—1·37°	6·65
27	4	1447	1012	15·92	7·35	—1·35°	15·09
28	4	1230	1017	14·91	6·85	—1·52°	10·66
			DURWANS.				
29	5	1650	1011	19·68	9·30	—1·23°	12·42
30	5	1492	1007	11·22	5·14	—·96°	8·53
31	5	1742	1006	9·87	4·21	—·71°	5·98
32	5	670	1024	15·31	7·11	—2·45°	9·92
33	5	732	1019	13·25	5·94	—1·86°	8·06
34	6	650	1011	5·56	2·61	—1·11°	4·88
35	5	830	1023	15·91	7·60	—2·24°	12·16
			BEARERS.				
36	4	1131	1006	6·99	3·22	—·70°	6·47
37	4	1408	1008	7·58	3·47	—·89°	10·91
			DOMES AND MEHTARS.				
38	4	884	1018	14·95	7·06	—1·48°	7·80
39	4	1120	1012	17·75	8·12	—1·20°	8·95
40	5	1002	1009	7·58	3·52	—1·05°	4·35
41	4	2216	1008	28·98	14·02	—1·16°	11·24
42	5	1080	1006	7·59	3·44	—·75°	4·81
43	5	1877	1006	14·77	7·22	—·68°	4·95
44	5	1552	1006	10·05	4·58	—·79°	7·85

We have now over two hundred analyses of the urine of students and others, all of whom had a free choice of food ; it will be our first duty to attempt to lay down, as accurately as possible from the number of observations at our disposal, standards for at least the more important constituents and to compare them with the standards generally accepted for Europeans in a colder climate. For this purpose it will be sufficient to strike an average for the total number of analyses without taking any note of the particular caste of the subject from whom the urine was obtained.

1. *Quantity of urine excreted in the twenty-four hours.*—As our investigations extended over a period covering both the hot and cold weather in Calcutta, the modification in the quantity of urine passed due to loss of fluids from the lungs and in sweat may be, to a large extent, neglected in the average amount obtained from the series.

It will be evident from the above figures that the quantity passed varies within very wide limits. In the average for each separate individual these limits were between 650 c.c. and 2216 c.c. and when we examine the daily quantities even wider limits are found—the lowest amount passed on one day being 330 c.c., and the largest quantity 2790 c.c. Variations more or less similar to these are observed in all countries and depending, as they do, on a large variety of circumstances are not of much importance—wide variations in the quantity of urine passed being quite compatible with health.

The average quantity found over the whole series of two hundred observations is 1177 c.c. This approximates very closely to that recorded for American students [1] in the winter, *viz.*, 1166 c.c., but, as would be expected, is below the average amount voided by an adult male European, *viz.*, 1200—1500 c. c. per day.

We may therefore fix our average for the quantity of urine passed in the 24 hours by Bengalis at from 1000—1300 c.c.

2. *The Specific Gravity.*—In Europeans the average specific gravity of normal urine is 1020 with variations in health of from 1015—1025, and, unless under exceptional circumstances such as after the imbibition of large quantities of fluids, it rarely falls below this ; in certain cases where fluids are withheld for some time the specific gravity may rise to 1035 or more.

When we compare these standards with the results shown in the above table it will at once be seen that there is a very marked difference. The limits of variation found in the urine of the Bengali are very much wider than is the case for the European ; as a rule, the specific gravity is on a lower scale.

On examining the average specific gravity—table I—of the urine of the individual cases we find it ranges between 1006 in *domes* and 1024 in the case

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(1) Manual of Physiology—Stewart.

of one student and one *durwan*. These limits practically cover the variations seen in the daily analyses also.

The average specific gravity over the whole series works out to about 1013, being slightly higher than this for the students alone, *viz.*, 1015.

We therefore find that, although a much larger proportion of the fluids got rid of from the body goes by the skin in tropical climates than in Europe, still the excretion of the total solids as measured by the specific gravity—also by the lowering of the freezing-point as will appear later—is less in quantity in Bengalis than in Europeans. This is exactly the opposite of what would be expected.

Rubner and his pupils have provided very accurate information upon the relation of climate and the evaporation of water from the lungs and skin (Von Noorden, Volume I, page 395). "It is least in temperate climates, it is greater at low temperatures, and is much increased at high temperatures. The next most important point is the relative humidity of the atmosphere. Air very nearly saturated with moisture can take up only a little more water-vapour, hence the body loses less water in damp than in dry air". Generally speaking the quantity of urine varies inversely with the amount of perspiration. The surplus left by the skin is excreted by the kidneys.

With regard to the amount of urine passed by the Bengali and its low specific gravity—the small quantity stands in close relationship to the small amount of total solids it contains and to the almost wholly vegetable character of the food—poor in nitrogen—upon which they live.

In the second part of this paper we shall return to this point, when the results of investigations on urine containing a much higher percentage of solids will be given.

3. *Urea.*—By far the greatest proportion of the nitrogen of metabolism is excreted by the kidneys in the form of urea. Von Noorden gives the percentage as being from 84—87; with animal diet the relative value is higher than with a mixed or a purely vegetable diet. "Not only the nitrogen of proteid is excreted in the form of urea, but the proteid decomposition products, glycocoll, leucin, and tyrosin, also give rise to an increase in urea corresponding to their contained nitrogen. This is also the case with asparaginic acid and ammonium salts. The nitrogen of nucleinic acid is also in part at least excreted as urea[1]".

The urea derived from all these different sources that is excreted by Europeans is generally accepted to be about 30—35 grammes per day or equal to about a 2 per cent. solution. It is the most important of the nitrogenous excretions of the body, being the chief end-product of the physiological oxidation of the proteids of the food.

(1) Von Noorden.—The Physiology of Metabolism, 1907.

Since, however, some of the nitrogen of proteids is eliminated in forms other than urea—as uric acid, xanthin, creatinin, etc.—even an exact determination. of the urea is insufficient to provide an accurate measure of proteid katabolism. We shall, therefore, for the present rest content with fixing the standard of urea from the analyses shown in Table I and discuss the significance of the results under the heading of the total nitrogen.

The smallest amounts of urea excreted occurred in the cases of one *durwan* and of two *domes;* these were 5·56 grammes and 7·58 and 7·59 grammes respectively for an average of five consecutive days' analyses. The maximum quantities for similar periods were 19·68 in a *durwan* and 18·17 grammes in (the average of) a student.

The average excretion of urea on the whole series of 200 observations works out to—students 12·95 grammes; *durwans* 12·97, and for *domes* and *mehtars* 12·91 grammes in the 24 hours. (In the case of the last class the averages hide the real facts ; their output of urea varied very much from day to day depending on their success or otherwise in obtaining a plentiful supply of cheap proteid food.)

A comparison of these standards of urea elimination with those for Europeans shows a very marked difference—the amount of urea excreted by the Bengali being less than half that usually accepted as the normal excretion of the European.

This important observation at once opened up the question of the bearing of the metabolism of the Bengali on recent researches[1] on the problems of nutrition.[2] Here we had ready-made the very conditions Chittenden had to plan and arrange in order to carry out his brilliant series of investigations; and that, too, in a whole community of millions of people accustomed to these conditions from early life. From a clinical point of view also, a knowledge of this low standard of urea excretion is a matter of practical importance in conditions requiring quantitative analyses of the urine.

4. *The total Nitrogen.* (Kjeldhal's method of estimation was adopted in every instance.)

In all problems concerning proteid metabolism in the body both as regards its character and extent the quantitative study of the nitrogenous excretion is of paramount importance.

By the determination of the total nitrogen excreted in the urine we have a measure of the total nitrogenous katabolism without regard to the specific forms in which the waste products are eliminated. The nitrogen excreted in the

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(1) Chittenden—Physiological Economy in Nutrition, 1905.
The Nutrition of Man, 1907.

(2) Leathes—Problems in Animal Metabolism, 1906.

sweat, milk, hairs, epithelial scales, intestinal secretions, etc., is so small that it may be neglected.

As nitrogen forms on an average about 16 per cent. of the proteid molecule, we are able to calculate from an estimation of the total nitrogen the amount of proteid material broken down in the body, one gramme of nitrogen in the urine requiring the katabolism of 6·25 grammes of proteid.

Further, since the human system is ever striving after a condition of nitrogenous equilibrium—so long at least as the weight of flesh is constant—we have, in this total nitrogen determination, a measure of the total proteid intake of the food. That such is the case is shown by the effect of a pure proteid diet on the output of nitrogen, every increase in the proteid of the diet resulting in a corresponding increase in the excretion of nitrogen.

,, The hungry or fasting man with his income entirely cut off, and consequently suffering from a heavy drain upon his capital stock, would be expected when suddenly supplied with fresh capital in the form of meat or other kind of proteid food, to hold on firmly to this important kind of food-stuff; but such is not the case.

" It is impossible, for example, to establish nitrogenous equilibrium by an income of proteid equal to what the individual during fasting is found to metabolise".[1]

The rise in proteid metabolism on an increase in proteid intake occurs to such an extent that the system is generally able to maintain itself in nitrogenous equilibrium on the most diverse amounts of proteid food. From this it must follow that the body is unable to store any excessive quantity of proteid except by the formation of muscle.[2]

In an average-sized man the total daily excretion of nitrogen, according to the generally accepted urinary standards for Europeans, varies between 14 and 18 grammes. This would correspond to from 88 to 112 grammes proteid katabolism in the 24 hours. It would also mean, if nitrogenous equilibrium were being maintained, that an equal quantity of assimilable proteid food would be required. (Slightly more than this is necessary to cover the loss of nitrogen in other excretions and secretions, but the amount is trifling and may be neglected.)

Now, let us examine how the nitrogen elimination in the urine of Europeans compares with the results obtained from the urine of the Bengali.

From the averages of four or five analyses on consecutive days—Table I—we find that the minimum average of nitrogen excreted is 3·40 grammes, the maximum being 9·04 grammes and the average for 124 observations on students working out at 6·05 grammes.

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(1) Chittenden—The Nutrition of Man, 1907.

(2) *Cf.* Von Noorden—The Physiology of Metabolism, 1907.

The minimum average for *durwans* will be seen to be 2·61 grammes; the maximum 9·30 grammes; the average amount of nitrogen eliminated on 36 daily analyses being 5·94 grammes. In the case of bearers, *domes* and *mehtars* similar figures were obtained, the average on 40 daily observations being 5·96 grammes.

The average of nitrogen excretion over the whole series of 200 analyses comes to the small amount 5·98 grammes daily. This very small total nitrogen excretion in the urine of the Bengali is in marked contrast to the 15 to 18 grammes excreted by Europeans and, from a scientific point of view, forms one of the features of the results. It means the metabolism of only about 37·50 grammes of proteid daily by the Bengali—a minimum below that obtained by Chittenden in his different experiments.

Even the average for five consecutive days in the case of the student who gave the highest results only comes to 56·50 grammes of proteid material metabolised per day; the minimum being so low as 21·25 grammes.

Chittenden was able after some months' training to maintain himself in nitrogenous equilibrium on 37—40 grammes proteid daily; but, as Von Noorden states, "All these experiments (Chittenden's) have to be examined from another point of view—namely, from that of the individual who has to maintain himself in nitrogenous equilibrium on this daily dietary and for a long period."[1]

In the present observations we are dealing with individuals who had a perfectly free choice of food and whose several conditions in life corresponded in every way to the great majority of the population of the country. We have, therefore, ideal conditions in which the lower limits of proteid metabolism is constantly present for an enquiry into the much discussed metabolic problem of the present day—the quantity of proteid in an ideal diet. To this we shall return in the second part of this paper. In the meantime it will suffice to point out that the total nitrogen in the urine being a measure of the proteid katabolism is also a measure of the nitrogenous material assimilated from the diet; so that we can calculate—with a fair degree of accuracy—the total proteid value of the food of the different individuals and classes examined during the period they were under observation.

This value works out, on the average, to be about 37·50 grammes of assimilable, proteid intake in the 24 hours. Chittenden's different groups were allowed quantities varying from 56, 63 to 67 grammes proteid daily, and on these they maintained a condition of nitrogenous equilibrium for many months.

The figure 37·50 grammes represents only about 32 per cent. of Voit's standard. [Voit's diet contains 118 grammes proteid.]

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(1) Von Noorden.—The Physiology of Metabolism.

5. *The freezing-point of the urine.*—So far as our observations go on the freezing-point of the urine of the Bengali—and we have made some hundreds besides those recorded on Table I—they would appear to show that the depression of the freezing-point varies directly with the specific gravity in normal urine and nothing of much importance can be learned by its determination that is not equally well shown by taking the specific gravity accurately. This subject has already been dealt with in another paper. [1]

As would be expected from the lower specific gravity and lower total quantity of solids, the urine of the Bengali causes less depression of the freezing-point than is the case in Europeans.

The average freezing-point of the urine for students is $-1{\cdot}52^\circ$ C; for *durwans* and bearers $-1{\cdot}35^\circ$ C, and for *domes* and *mehtars* $-1{\cdot}01^\circ$ C; on the whole series the average obtained was $-1{\cdot}24^\circ$ C.

The variations met with are very great—ranging between $-0{\cdot}68^\circ$ C and $-2{\cdot}45^\circ$ C. In Europeans the freezing-point is usually -2° C to $-2{\cdot}6^\circ$ C.

With regard to the question of the value of the determination of the freezing-point as a means of measuring the work done by the kidney we cannot agree with the view that the quantity of urine passed multiplied by the difference in the freezing-points of the urine and blood—the formula $Q\,(\Delta - D)$—is any index of the work of the kidney in excretion.

We have many observations in which the freezing-point of the urine was actually less depressed than that of the blood, which would mean that the work of the kidney was a negative quantity; and yet a large quantity of dilute urine containing quantitatively the normal amount of solids was being voided. For further information on this point we would refer to Hill and Moore's work on the subject.[2]

6. *The Chlorides.*—An examination of the quantity of chlorides was made in every instance, as it was expected the percentage and total quantity present would be high on account of the largely vegetable character of the diet. In Europeans the average quantity excreted per day is about 15 grammes, varying directly with the amount ingested with the food.

The variations in the amount excreted met with in Bengalis will be seen from Table I to be from 4·35 grammes to a maximum of 19·30 grammes on the average figures of four or five consecutive daily analyses.

The average excretion of chlorides over the whole series of analyses is 9·43 grammes daily,—a quantity considerably lower than the average for Europeans.

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(1) McCay.—*The Lancet*, 1st June 1907.

(2) Hill.—Recent Advances in Physiology and Bio-Chemistry, 1907.

This is the more remarkable when the almost entirely vegetable nature of the diet is considered. Bunge [1] has called attention to the fact that among men and animals the craving for salt is limited, for the most part at least, to those living on vegetable food. On a purely animal diet there is no desire for salt. Bunge explains this phenomenon in the following manner. Most vegetable foods contain a large quantity of potassium and these salts on absorption react in the blood with sodium chloride, giving rise to potassium chloride and potassium sulphate; both these salts are removed at once by the kidneys since they are both practically foreign to the blood; so that the blood in this way loses some of its sodium chloride; hence the craving for more salt with vegetable food.

We were therefore prepared to find a high average in the salt excretion of the Bengali as he had a free choice in the quantity of salt taken with his vegetable food. But such is not the case; the quantity got rid of by the kidneys is actually lower than in Europeans.

These results are in striking contrast to those shown in Table XIII, where the intake and output of salt is very excessive. This, however, is a subject to which we shall return when dealing with the metabolism of the Bengali.

The quotient $\frac{\Delta}{\text{Na Cl\%}}$ (Δ=freezing-point of urine) representing the ratio of the total concentration to the sodium chloride concentration varies relatively in Europeans, within narrow limits—diet, according to Von Koranyi, having no influence.

As has already been shown,[2] the limits of variation met with in the Bengali are very much wider, being in the above series from ·72 to 1·80, compared with variations in Europeans lying between 1·23 and 1·69. The quotient $\frac{\Delta}{\text{Na Cl\%}}$ in the Bengali nearly approaches unity.

The second table—Table II—gives the results of observations on some of the other constituents of the urine not mentioned in Table I. These include uric acid, phosphates, sulphates, and in a few cases the organic sulphates. Although the number of these analyses may be considered too limited they serve to give some indication of what the standards under these headings of the urine of Bengalis work out to be.

As already stated, investigations having for their object the further study of the different forms of nitrogenous waste products other than urea are at present being carried out. These will include in addition to urea—

(*a*) The ammonia nitrogen—that is, the nitrogen found in the form of ammonia salts which liberate free ammonia on the addition of a fixed alkali.

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(1) Bunge.—Physiologie des Menschen, Vol. II, 1901.

(2) McCay.—*The Lancet*, June 1907.

(*b*) The kreatinin nitrogen—that is, the amount excreted as kreatinin indicative of a special form of metabolism. According to Folin this nitrogen is probably a measure of the constant variety, which he calls *endogenous* or tissue metabolism.[1]

(*c*) The purin-bodies nitrogen (including uric acid, xanthin, hypo-xanthin)—these probably also indicate a special form of metabolism.

7. *The Phosphates.*—The average amount of phosphoric acid in combination with lime magnesia and alkali excreted by Europeans is usually said to be from 2—3·5 grammes daily, and its relation to the excretion of nitrogen is as 5 or 6 : 1. The average in Bengalis from the analyses shown on Table II is 0·918 grammes in the 24 hours. This is little more than one-third of the amount got rid of by the European, but, as will be seen, its relation to the nitrogen in the urine of the Bengali works out to practically the same as in the European.

The phosphoric acid in the urine is largely determined by the nature and quantity of the food; it is not, however, furnished by ordinary proteids, but by tissues rich in nuclein.

The "flesh" of the body contains nitrogen and phosphoric acid in certain proportions. If "flesh" be put on, phosphoric acid is retained; when the muscles waste, proteid is lost and phosphoric acid is also lost from the body: the loss of proteid and phosphoric acid is in the proportion in which they are present in muscle.

In human muscular tissue the relation between nitrogen and phosphoric acid is $\frac{N}{P_2O_5} = \frac{100}{13{\cdot}7} - 7{\cdot}3$ (Von Noorden).

Table II.

No.	No. of observations (average).	Total quantity in c. c.	Phosphates grms.	Uric Ac. grms.	Total Sulphates grms.	Organic Sulphates grms.
1	3	1063	·970	·552	1·62	
2	2	1530	1·462	·535	1·65	
3	2	1215	1·012	·631	1·69	
4	3	1113	·927	·467	1·50	·148
5	2	1210	·859	·363	1·816	·142
6	2	625	·735	·388	2·78	·191
7	4	1324	·781	·536	1·30	·143

(1) Otto Folin.—Laws governing the Chemical Composition of Urine. A Theory of Proteid Metabolism. American Journ. of Physiology, Vol. XIII.

Table II—*continued.*

No.	No. of observations (average).	Total quantity in c. c.	Phosphates grms.	Uric Ac. grms.	Total Sulphates grms.	Organic Sulphates grms.
8	2	1190	·967	·410	1 30	
9	2	845	·886	·531	1·94	
10	2	965	·852	·315	1 94	
11	2	756	·835	·333	1·852	
12	3	1110	·734	·364	2·110	

8. *The uric acid.*—Healthy Europeans excrete from ·3 to ·75 grammes of uric acid daily; if large quantities of animal food rich in purin-bodies, such as thymus or sweet-bread, are taken, the daily output may be increased up to 1·5—2 grammes.

It does not arise from the disintegration of simple albuminous bodies but is chiefly derived from the nucleins of the food.

The excretion of uric acid, on a diet free as possible from purin bodies, is fairly constant for each individual; it arises from the nuclein bodies of the tissues and has been called endogenous in contradistinction to the exogenous uric acid originating in the nucleins of the food.[1]

The present investigations on the uric acid output of the Bengali give an average excretion of 0·452 grammes daily, which is about the same as that of Europeans on a purin-free vegetable diet. The "dhall" (pulse) in the food of the Bengali contains a high percentage of purin bodies (Walker Hall), so that the total quantity of uric acid excreted covers that derived from the "dhall" and that due to endogenous metabolism; this latter amount in the Bengali must be very small. It will be of interest to obtain the excretion of this endogenous uric acid in the Bengali (by giving a purin-free diet) and compare its amount with the results obtained in Europeans.

9. *The Sulphates.*—Nearly the whole of the sulphur taken in the food reappears in the urine; when completely oxidised it occurs as free or combined sulphuric acid, and in organic combinations as neutral or organic sulphur. The total sulphuric acid excretion under ordinary nutritional conditions in Europeans is from 1·5—3 grammes daily; and the quantity of combined sulphuric acid in a healthy European on an average diet is from 0·12—0·25 grammes a day.

In Bengalis the analyses would show, on the whole, a diminution in the

(1) Folin.—American Journ. of Physiology, Vol. XIII.

total elimination of sulphates compared with Europeans. The average works out at 1·88 grammes.

The combined sulphuric acid occurring in the urine as aromatic products—such as indol, skatol, etc.—from the few analyses carried out averages 0·156 grammes a day.

The quotient ethereal sulphuric acid over the total sulphuric acid in Europeans is usually $\frac{1}{10}$ to $\frac{1}{12}$; this relationship holds good also, so far as our observations go, for the Bengali.

The old view that this quotient gave a measure of the amount of intestinal putrefaction has now been given up; the denominator of this fraction, the total sulphuric acid, depends on the total amount of albumen consumed and has therefore no connection with putrefaction.[1]

This finishes the observations on the standards of urinary constituents in the Bengali. It would make for clearness, perhaps, if they are compared in the form of a table with those found in Europeans.

Table III.

Constituents.	In European.	In Bengali.
Quantity	1440 c.cs.	1200 c.cs.
Specific Gravity	1020	1013
Urea (Grammes) . . .	35	13
Total Nitrogen (Grammes) . . .	18	6
Freezing-point	—2·5° C.	—1·24° C.
Chlorides (Grammes)	15	10
Phosphates (Grammes) . . .	3·5	0·918
Uric Acid (Grammes)	0·75	0·452
Sulphates (Grammes)	2·5	1·880

B. The Blood.

The very marked differences met with in the urine of the Bengali would *a priori* lead us to suspect something of a similar nature also in the blood compared with its composition in the European. The usual well-recognised

(1) Von Noorden.—The Physiology of Metabolism, 1907.

methods of blood examination have been made use of, and newer methods employed and modified to push the examination as far as possible in order to obtain a knowledge of any departure from European standards.

The result of the urine analyses has been shown to be that the percentage or total quantity of the constituents excreted was on a very much lower scale than is the case in Europeans; the blood being the source from which the urine is derived, we should expect to find some modification in its chemical composition and formed elements.

Let us examine the evidence at our disposal.

1. *The corpuscular enumeration and hæmoglobin value.*—The ordinary routine examination—enumeration of the red and white corpuscles and the estimation of the percentage of hæmoglobin—was carried out in 170 different persons; about two-thirds of these were students, the remaining third was composed of many different classes. All the individuals taken into account were in good health and were, as far as could be judged, typical of the blood condition of the Bengali.

As there is nothing to be gained by giving the individual analyses in full detail, we publish in Table IV the averages of the different constituents for stated percentages of hæmoglobin.

Table IV.

No.	No. of observations.	Average percentage of hæmoglobin.	Average of R. B. C.	Average of W. B. C.	Class.
1	9	92	5,520,000	10,400	Hb.—90 per cent. or over.
2	30	87	5,500,000	9,800	Hb.—85—90 per cent
3	60	81	5,300,000	9,700	Hb.—80—85 „
4	27	76	5,200,000	8,700	Hb.—75—80 „
5	20	71	4,810,000	8,000	Hb.—70—75 „
6	10	67	4,800,000	7,650	Hb.—65—70 „

In the remaining 14 observations the corpuscles and hæmoglobin were below the above standards, so that the individuals could not be considered healthy. From an examination of the above table we may conclude—

(*a*) The average number of red blood corpuscles per c.m. of blood in the Bengali is greater than in Europeans. In over 80 per cent. of those examined this average works out to be 5,300,000 per c. m. In European healthy adult males the average number of red blood corpuscles was 5,190,000 per c.m. over 113 observations.[1]

(*b*) The white blood cells are, on the average, slightly more numerous than in Europeans. On 156 observations the average number is 9000 per c.m.

(*c*) The hæmoglobin estimation (Haldane's modification of Gower's method—the carbon monoxide method—) was followed in every instance. The limit of error in this method of estimation is not more than 1 per cent.

The blood of the Bengali shows a very decided deficiency in hæmoglobin compared with the European. On the 156 observations shown on above table the average amount of hæmoglobin was only 79 per cent. ; and over 75 per cent. of the persons examined possessed only 81 per cent. of hæmoglobin.

When we recall that the Bengali has a greater number of red blood cells than the European and, at the same time, shows a marked deficiency in the percentage of hæmoglobin, it follows that the hæmoglobin value per red cell is much below the normal European standard.

In Europeans the hæmoglobin value per red corpuscle varies normally from 0·95 to 1·1.[2] In Bengalis, on the other hand, this ratio is about 0·75 ; this means, instead of each red blood corpuscle being in possession of its normal amount of hæmoglobin, it has, on the average, only about 75 per cent. of that quantity. It will be evident from these facts that the oxygen-carrying capacity of the blood must be seriously affected.

2. *The specific gravity of the blood.*—In the Bengali the specific gravity of the blood averages in adult males 1057. This is slightly higher than the average for Europeans. Stewart[1] gives an average of 1054·4 on 165 observations. The higher specific gravity of the Bengali is probably due to the greater number of corpuscles, and, as will be seen later, to the increased salt concentration of the blood compared with that of Europeans.

3. *The chemical composition of the blood.*

(*a*) In order to obtain sufficient blood for analysis we had resort to the method of "pooling." A measured quantity—about $\frac{3}{10}$ c.c.—of blood was taken from each of a number of individuals, usually about

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(1) Stewart.—Manual of Physiology, 1906.

(2) Schafer.—Text-book of Physiology.

15—20; the quantity thus obtained was collected in a weighed flask.

In this way we not only got sufficient blood to carry out analyses, but also obtained the average composition over the number of individuals whose blood was taken.

Having weighed the flask and blood, by deducting the weight of the empty flask, we had the weight of the blood made use of.

This was examined for total nitrogen by Kjeldahl's method and the result noted.

(*b*) In a similar way the blood was "pooled" into a platinum dish—weighed before and after.

From this blood water was evaporated off in a water bath and then in a dessicator. On weighing again we obtained the total solids remaining, and the water evaporated.

The solid matter was incinerated in a red hot flame to get rid of all organic material and, this being completed, the capsule was weighed again and the inorganic salts present estimated.

In Table V we present the averages of the results thus arrived at regarding the blood of the Bengali.

Table V.

	European (Schmidt).	Bengali.
	Percentage.	Percentage.
Water	78·87	79·88
Total Solids	21·13	20·12
Proteids	19·17	18·23
Salts	0·78	1·06

(*c*) Another method of examination made use of on a fairly large scale was the estimation of the total salt concentration of the serum (expressed in terms of NaCl) by Wright's hæmolysis method. This is an exceedingly simple and easily carried out means of examining the blood. A full description of the method will be found in Wright's original papers; [1] its application to the Bengali has already been worked at.[2]

(1) *The Lancet*—2nd April 1904 and 21st October 1905.
(2) M'Cay—*The Lancet*, 1st June 1907.

The principle of the method is to find the particular dilution of a normal solution of sodium chloride, two volumes of which will exactly cause hæmolysis of one volume of the blood. Let this dilution be $\frac{N}{45}$; this is equivalent to a 0·130 per cent. solution NaCl.

Now, in a similar way the dilution of the serum with distilled water necessary in order that two volumes of the diluted serum may cause hæmolysis of one volume of blood is found.

Therefore we have for example :—

$\frac{N}{45} = \frac{Serum}{8} =$ ·130 % NaCl therefore Serum = 1·040 % NaCl.

On Table VI we present the results obtained in 84 different observations on the total salinity of the serum.

Table VI.

Serial No.	No. of observations.	Dilution of normal solution of NaCl, two vols. causing hæmolysis of one vol. blood.	Dilution of serum necessary for two vols. to hæmolyse 1 vol. blood.	Total salt concentration of serum.	Class.
		Per cent.		Per cent.	
1	40	$\frac{N}{45}$ = ·130	7·94 fold	1·033	Student.
2	7	$\frac{N}{49\ 10}$ = ·119	9·00 ,,	1·071	Dome & Mehtars.
3	37	$\frac{N}{52·54}$ = ·1112	9·52 ,,	1·058	Mixed Classes.

(*d*) A fourth means of examination—for a knowledge of which our thanks are due to Captain Harvey, I.M.S., and Captain McKendrick, I.M.S., both of the Pasteur Institute, Kasauli, the originators of the method—was made use of to estimate the total chlorides of the serum.[3] Captain Harvey was good enough to demonstrate the technique before the method was published. Shortly, it consists in the titration of a known solution of $AgNo_3$ against the serum—a thin strip of chromate paper acting as indicator. Its great advantage is that the estimation can be carried out with so small an amount as 50 c.ms. of serum; specially graduated capillary pipettes being essential.

(3) Harvey and McKendrick—Scientific Memoirs, No. 30.

We have found it better to use as large an amount of serum as possible so long as the serum is clear; the error of observation is thus reduced to a minimum.

The average amount of chlorides present in the serum of the Bengali over a large series of investigations by this method works out at from ·70—·78 per cent.; varying within very narrow limits.

Now, let us examine the results arrived at from these different methods of investigation :—

i. From the chemical composition shown on Table V it is evident that the proteid content is on a lower scale in the Bengali compared with the European.

This is in spite of the fact already shown that the corpuscular element is increased in the Bengali; it is, therefore, evident that the deficiency in the floating proteids of the serum is even greater than would appear from the table. When we recollect that it is from these floating proteids—serum globulin and serum albumen—that the different nitrogenous tissues of the body derive their nutrition, it will be abundantly apparent that these facts have a very important bearing on the sufficiency or otherwise of the diet and more particularly of the proteid element in that diet.

In this connection it is interesting to note that a sparing diet ($1\frac{1}{2}$ litres of milk a day) will cause a marked diminution in the amount of serum albumen and serum globulin in so short a time as a week.(1)

ii. The total concentration of the serum or its total salinity.

From a comparison of Tables V and VI it will be found that the quantitative estimation of the salts corresponds closely with the percentage obtained by Wright's hæmolysis method—1·06 per cent. and 1·054 per cent.

Professor Wright holds that what is measured by his methods is probably the chlorides(2) and not the total salts; to this we are unable to agree. We have found that the salinity of the serum as shown by the hæmolysis method is always greater than the percentage of chlorides estimated in the way devised by Harvey and McKendrick already mentioned. This is strikingly borne out by some experimental results obtained from the effect of small or large doses of quinine sulphate on the concentration of the serum in healthy adults. The typical results of a few observations are shown in Table VII.

(1) Landau—Osmostischen Druck des Blutes.

(2) *The Lancet*—2nd April, 1904.

Table VII.

Serial No.	Total concentration of serum by Wright's method.	Chlorides of serum by Harvey-McKendrick method.	Quinine Sulph given thrice daily.	Total concentration of serum by Wright's method.	Chlorides of serum by Harvey-McKendrick method.	
	Per cent.	Per cent.		Per cent.	Per cent.	
1	·875	·728				
2	·928	·73				
3	1·06	·75				
4	1·07	·763	Gr. V.	·965	·724	
4	·965	·724	„ V.	·914	·723	
4	·914	·723	„ V.	·863	·705	Consecutive days from 8th August 1907.
4	·863	·705	„ X.	·701	·612	
4	·701	·612	„ X.	·876	·720	
4	·876	·720	„ X.	1·061	·758	
4	1·016	·758	„ XX.	1·04	·754	

[Many more observations were made on the effects of quinine sulphate in health and the invariable result found was the immediate decrease in the salt concentration of the serum—a negative phase—followed by a return to the normal degree of salinity. The effect of quinine sulphate would therefore appear to be to lessen the resisting power of the red blood corpuscles to hæmolysis ; and the larger the dose the more quickly this resisting power is reduced. The bearing of these results on the administration of large doses of quinine sulphate as a factor in the causation of hæmoglobinuria is obvious and opens up a very interesting problem.][1]

In Europeans the total salinity of the serum is ·90—·95 per cent. Many authorities, however, give a lower value. In the Bengali the figures vary from 1·05—1·09 per cent. Wherever there was any appearance of anæmia we always found the salinity increased, while, on the other hand, the healthier the individual looked the lower the salt concentration of the serum turned out to be.

(1) McCay—*Ind. Med. Gazette*, February 1908.

It has been shown [1] that in pathological conditions the salinity, measured in this way, is greatly increased in œdema and anæmia. The lower percentage of hæmoglobin present in the blood of the Bengali would appear to have a distinct connection with the higher salt concentration of the serum; the salinity of the serum varying inversely as the hæmoglobin value of the blood. What the explanation of this is we are unable to say. It would appear, however, that in those diseases in which the salt concentration of the serum is markedly increased —anæmia, Bright's disease, etc.—the red blood corpuscles are more resistant to a dilution of the serum than in health. That this is not due to a retention of chlorides by the blood is evident from the fact that, although estimation of the total chlorides of the serum by the Harvey-McKendrick method shows a decided increase, the increase is nothing like sufficient to account for the very high percentage obtained by Wright's hæmolysis method. Some other factor, at present undetermined, increasing the resisting power of the red blood corpuscles and which cannot be explained by osmosis or mere isotonicity, must be present. However, in health or even in the degree of anæmia met with in the Bengali, the results can be completely explained by osmosis ; the proof of this statement will be found in the close agreement of the percentage of total salts estimated by the ordinary quantitative means and by Wright's hæmolysis method.

iii. The chlorides of the serum—

Voila's average value for human blood serum—0·55 per cent. NaCl—agrees very closely with the faultless results obtained by Schmidt, Wannach and Biernacki.[2] This is the quantity usually accepted for the blood serum of Europeans. Landois [3] gives the total inorganic salts of human blood serum at ·85 per cent., the chlorides alone being ·50 per cent.

As we have already stated, the average percentage of chlorides found in the blood serum of the native of Bengal varies within narrow limits in health and is usually from 0·72 per cent. to 0·75 per cent. We tabulate a few of the estimations carried out showing the total chlorides of the serum of the Bengali.

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(1) M'Cay—*The Lancet*, 1st June 1907.

(2) Von Noorden—The Physiology of Metabolism, 1907.

(3) Landois—A text-book of Human Physiology, 1904.

Table VIII.

Serial No.	Caste—Class.	Total salt concentration of serum by hæmolysis method.	Total chlorides of serum estimated by Harvey-McKendrick method.
1	Hindu Durwan . .	0·875 per cent.	0·728 per cent.
2	„ Dome . .	0·890 „	0·710 „
3	„ Student . .	0·970 „	0·770 „
4	„ Student . .	0·870 „	0·720 „
5	„ Dome . .	1·070 „	0·763 „
6	„ Bearer . .	1·016 „	0·754 „
7	„ Durwan . .	1·060 „	0·750 „
8	„ Student . .	1·320 „	0·725 „
9	„ Coolie . .	0·928 „	0·730 „
10	„ Bearer . .	1·090 „	0·723 „

The average we have obtained works out at 0·735 per cent. which would be 0·18 per cent. to 0·20 per cent. of chlorides more than is present in the blood serum of the European.

This extra amount of chlorides in the blood serum of the Bengali would completely account for the higher total salinity of his serum, *viz*: 1·06 per cent. to 1·09 per cent. compared with the total salt concentration of the serum of the European, *viz.*, 0·85 per cent. to 0·90 per cent.

As already mentioned, the higher salt concentration would assist in raising the specific gravity and also, in all probability, would tend to increase the alkalinity of the blood. With regard to the hæmalkalimetry of the Bengali we are not in a position to make any definite statement, but an investigation based on the valuable methods introduced by Moore and Wilson [1] is being carried out.

The values to be obtained for the basic reactivity of the inorganic salts of the serum to di-methyl-amido-azo-benzol should give important results in the Bengali and opens up a wide field of research, both from a physiological and pathological aspect.

4. *The coagulability of the blood.*—A series of observations was carried out determining the time of coagulation, the method introduced by Wright being

(1) A Clinal Method of Hæmalkalimetry; Moore and Wilson;—*Bio-Chemical Journal*, 1906.

followed in every case. The time required for coagulation in Europeans is usually stated to be from 4 to 6 minutes.

In the Bengali the clotting of the blood is very much quicker than in the European. The average time of coagulation obtained in our series is from $1\frac{3}{4}$—$2\frac{1}{4}$ minutes. These observations were all carried out at blood heat.

The short time required for clotting in the Bengali is well-known to all workers on blood; the ordinary finger-prick, from which in the European a comparatively large quantity of blood can be obtained, in the Bengali rapidly closes and becomes sealed by a clot.

The cause of this rapidity of coagulation is difficult to explain. One factor probably is the numerically high limits of the corpuscular elements and more particularly the numerically high average of the white corpuscles in the blood of the Bengali. Another factor which we consider of great importance is the greater salinity of the blood found in the people of this province. The effect of this increased salinity is in all probability to increase the degree of alkalinity of the blood and also to increase the facility with which the blood clots. It may be that with this increased salinity we have at the same time a higher concentration of calcium salts in the blood of the Bengali than in the European; any increase in the number of calcium ions present, within certain limits, will favour coagulation just as a deficiency seems occasionally, as in hæmophilia, to be responsible for a diminished coagulability of the blood.

5. *The blood pressure in the Bengali.*—In healthy adult male Europeans the normal average pressure of the blood in the brachial artery varies from 110 to 130 mm. Hg., in the sitting posture. This pressure varies comparatively little in health for the same individual when measured under similar circumstances and on the same artery.

We have taken readings of the blood-pressure in the brachial artery in over 500 adult male Bengalis. The instrument used was Riva Rocci's sphygmomanometer with Recklinghausen's broad armlet. The pressure was noted at the disappearance of the pulse in the radial artery—the arm being placed on a level with the heart. All readings were taken with the person examined in a sitting position.

On the whole series the average blood pressure (systolic) of the Bengali works out to be just under 100 mm. Hg., a good average systolic pressure in the brachial artery lying between 95 and 105 mm. Hg.

The blood-pressure of Bengalis is therefore on a much lower scale than is the case in the European — a condition that must affect their vigour and energy. The factors in the causation of the lower type of pressure of the Bengali are, probably, manifold. That difference in climatic conditions is not the chief cause is shown by the fact that Europeans living in the same

climate do not exhibit, even in the hot, moist atmosphere of Calcutta, such a low average blood pressure as is seen in the Bengali. As would be expected, the vasomotor system becomes more or less accustomed to the new conditions and regains its function of maintaining the tonicity of the vessels in the area of peripheral resistance; this in its turn is one of the principal factors in the maintenance of blood-pressure. In the consideration of this question the force and frequency of the heart-beat is a factor that cannot be neglected. In the second part of this paper we shall have evidence to bring forward regarding the physical development of the Bengali and his power of muscular exertion which will tend to show that the capacity for muscular work is decidedly superior in the European.

From a similar line of argument we hold that the same causes that effect the superiority of the European's ordinary voluntary muscles also maintain the muscular tissue of the heart in a higher state of nutrition and permit of the superior force and vigour of its contraction.

Whatever the cause or causes may be, the pressure of the blood in the arteries of Bengalis is from 15 per cent. to 22 per cent. lower than in Europeans. It is worth recalling in connection with this that the percentage of hæmoglobin is also only about 75 per cent. to 80 per cent. of the European standard.

To a consideration of this subject we shall return later; at present, we may close our investigations on the blood of the Bengali by collecting the results in the form of a table comparing them with normal European standards.

Table IX.

No.	Headings.	European.	Bengali.
1 . . .	Red blood corpuscles .	5,000,000	5,300,000
2 . . .	White corpuscles .	6000—8000	9000
3 . . .	Hæmoglobin . .	100 per cent.	81 per cent.
4 . . .	Specific gravity . .	1054—1057	1055—1058
5 . . .	Proteids . . .	19·17 per cent.	18·23 per cent.
6 . . .	Total solids . .	21·13 ,,	20·12 ,,
7 . . .	Salts	·78 ,,	1·06—1·09 ,,
8 . . .	Chlorides (Serum) .	·55 ,,	·72—·75 ,,
9 . . .	Time of coagulation .	4—7 Mins.	$1\frac{3}{4}$—$2\frac{1}{2}$ Mins.
10 . . .	Systolic blood pressure in brachial artery.	115—130 mm.Hg.	90—105 mm. Hg.

Part II. The Metabolism of the Bengali and its bearings on Dietary Standards.

In the first part of this paper we have shown from the analyses of the urine of a large number of different individuals comprising several classes that the total amount of proteid metabolised on the average by the Bengali is only 37·50 grammes per day and that, therefore, only a slightly greater quantity than this of assimilable proteid is absorbed from their ordinary diet.

On the other hand, according to Carl Voit, who is held in the very highest estimation as a student of nutrition, an adult man of average body-weight (70—75 kilos.) doing moderate muscular work requires 118 grammes of proteid, of which 105 grammes at least should be absorbable.

This is the standard perhaps most generally accepted amongst Europeans as covering all the nitrogenous requirements of the body; it will be evident, if our results as stated above are correct, that the people of Bengal live and prosper on a diet that contains about one-third of the amount of proteid considered by Voit absolutely necessary.

Before proceeding to a detailed examination of the bearing of the metabolism of the Bengali on diets, we shall very briefly review the different theories that have been propounded to explain the rôle of the nitrogenous materials of the food in the general economy of nutrition. The discussion hinges on the nature of the material used up in connection with muscle work; on the answer to this will depend, in a large measure, the kind of food-stuff that should be taken in to supply the part used up. Chittenden[1] makes a clear statement of the point at issue in these words: "If the energy of mechanical work, the energy of muscular contraction, comes from the breaking-down of proteid matter alone, then obviously excessive muscular work would need to be accompanied, or followed by a generous supply of proteid food. If, on the other hand, external work means liberation of energy solely from non-nitrogenous materials, then it is equally clear that fats and carbohydrates are the proper foods to offset the drain incidental to vigorous muscular action."

The view advanced by Liebig and modified later by Pflüger was the dominant one for years. According to this theory the products of the digestion of proteid food-stuffs are built up into the protoplasmic molecules of the living cells, and there, in a readily oxidisable form, are available for the supply of energy; further, that proteid material alone is the one and only source of the energy of muscular contraction. Liebig's view, if true, should entail a great increase in the output of nitrogenous waste-products on the liberation of muscle energy; but, from faultless experiments, such was not found to be the case; variation in the amount of work performed is practically without influence

(1) Chittenden. The Nutrition of Man, 1907.

on the excretion of nitrogen. On the other hand, increased muscular exertion does entail a marked increase in the consumption of oxygen and in the excretion of carbon dioxide. Non-nitrogenous matter had, therefore, to be considered as a source or as the main source of the energy of muscular contraction.

To-day an hypothesis[1] almost diametrically the opposite of the theories of Liebig and Pflüger is held in much favour. According to this view the nitrogen of the proteid food-stuffs is rapidly eliminated from the products of digestion, and excreted in the form of urea, whilst the carbohydrate moiety of the proteid molecule forms, on oxidation, the main source of the energy-supply of the organism. The tissues themselves undergo degradation under exceptional circumstances only, as, for example, when the supply of food is insufficient to produce the energy required by the body. According to those who hold this view, as the main source of energy is the oxidation of the non-nitrogenous part of the proteid molecule,[2] nitrogenous food should play a comparatively subordinate rôle in the general economy of nutrition, and its function as a source of energy should be capable of being entirely replaced by carbohydrates and fats.

The researches of Chittenden, Siven and others have all been directed to the establishment of this conception; Chittenden's works in particular being an earnest plea for moderation in the proteid intake. This view clearly recognises the all-importance of nitrogenous food in the nutrition of the body. It is the only source of nitrogen available in the system and the only source from which the proteid-containing tissues of the body can be maintained. It is, therefore, obvious that "there must be a certain amount of true proteid tissue broken down each day, independent of that larger metabolism coincident with the intake of proteid food." We have therefore to distinguish between two forms of metabolism—the metabolism of energy and the metabolism of tissue—which are quite distinct from each other. The tissue changes should be fairly constant under ordinary conditions for any given individual; the one factor determining their extent being the weight of the true tissue elements of the body.

In connection with this view Folin[3] has recently made a further advance in our knowledge. He has shown that the change from a nitrogen-rich to a nitrogen-poor diet is followed by significant changes in the composition of the urine. As would be expected, the output of urea diminishes in amount, but, more important than this, it diminishes relatively in comparison with the other nitrogenous constituents. On the other hand the kreatinin and sulphur output remains constant, whether the diet be highly nitrogenous or not.

(1) Speck. Ascher and Spiro's Ergeb. der Physiol. Bio-Chem., 1903.
(2) Schryver; Bio-chemical Journal, 1906.
(3) Folin; American Journal of Physiology, 1905.

Folin therefore concludes that metabolism may be considered under two heads, *viz.*:—an endogenous metabolism due to the constant tissue changes above referred to, which is responsible for the kreatinin and sulphur (neutral) of the urine, and exogenous metabolism, varying directly with the proteid intake and which is responsible for the greater part of the urea of the urine. According to this view the only nitrogenous matter necessary for the up-keep of the nitrogenous tissues of the body is the amount necessary to supply the waste represented by the endogenous metabolism, and which is excreted in the form of kreatinin.

There are, therefore, widely divergent views held with regard to the rôle of the nitrogen of the food; on the one hand we have the theory that all the absorbed proteids are built up into the living protoplasm of the tissues and that large amounts are necessary to maintain the organism in full bodily vigour; on the other hand we have the view held by Folin and others that only those quantities are necessary that are required for the repair of tissue waste, and that it is from the non-nitrogenous constituents of the food that the source of muscular energy is obtained.

It is generally admitted that the energy of muscular contraction can come from all three classes of organic food-stuffs, but, so long as non-nitrogenous food is supplied in adequate quantity or is stored up in the tissues, muscular energy is derived principally from that source. When it is gone, proteids are attacked, vigorous work being then attended with increased nitrogenous waste. The evidence in favour of this view is overwhelming and it may be accepted as a sound working basis.

The question is, therefore, narrowed down to this:—

Accepting the view that the energy of muscular contraction can be, and is normally supplied by non-nitrogenous food-stuffs, are we, therefore, justified in advocating a large decrease in the proteid intake from Voit's standard?

Is the amount of proteid necessary for the repair of true tissue waste—Folin's endogenous metabolism—and that necessary to cover the loss from external secretions, hairs, epithelial scales, etc., all that is required by the system? If so, then a few grammes of proteid a day is all that is absolutely essential.

In other words, are we justified in stating that a diet should contain only the minimum amount of proteid on which nitrogenous equilibrium can be maintained? If we are not justified in this belief and admit that an extra quantity of proteid above the minimum necessary for nitrogenous equilibrium is for the welfare of the body, then where is the line to be drawn? The question at once arises, if a small extra amount of proteid beyond actual requirements is for the advantage of the proteid-containing tissues, will a larger quantity not be to their

still greater advantage? We submit that the evidence obtained from a study of metabolism of the Bengali has a distinct bearing on the answers to these questions and throws a certain amount of light on the correctness or otherwise of the different opinions put forward.

It will be at once apparent that the amount of proteid metabolised by the Bengali—from 37 to 40 grammes a day—approaches the lower limits of physiological requirements and that therefore, according to the arguments advanced by Chittenden, the Bengali should show in a marked degree "many suggestions of improvement in bodily health, of greater efficiency in working power, and greater freedom from disease, in a system of dietetics which aims to meet the physiological needs of the body without undue waste of energy and unnecessary drain on the functions of digestion, absorption, excretion and metabolism in general; a system which recognises that the smooth running of man's bodily machinery calls for the exercise of reason and intelligence and is not to be trusted solely to the dictates of blind instinct or the leadings of a capricious appetite."[1] It will be our desire in the following pages to bring forward all the evidence at our command with regard to the effects of the low proteid intake of the Bengali and its bearing on the views put forward by Chittenden and his followers. This we shall try to do in a manner as unbiassed as possible, leaving the facts as we have found them to speak for themselves.

I.—The deductions from the total nitrogen of the Urine.

We have shown in the first part of this paper that the average daily amount of proteid material metabolised by the Bengali was about 37·50 grammes; this is the equivalent of 6 grammes of nitrogen.

The average weight of the Bengali over a very large series of weighments (see later under body-weight) works out at from 52 to 54 kilos. The average Bengali would therefore metabolise daily from 0·115 to 0·111 gramme of nitrogen per kilo of body-weight. This amount is practically identical with that stated by Chittenden to be quite sufficient.

He states "we have found that the average need for proteid food by adults is fully met by a daily metabolism equal to an exchange of 0·12 gramme of nitrogen per kilo of body-weight."

That this quantity was adequate to maintain the individuals investigated in a condition of nitrogenous equilibrium indefinitely is evident from the fact that the diet was not restricted but entirely a matter of choice; also, those examined were quite up to the standard of the adult Bengali in health, body-weight, physical strength and mental attainments. Further, the averages obtained are based on

(1) Chittenden. The Nutrition of Man, 1907.

a sufficiently large number of individuals to eliminate the error due to any one subject falling much below the ordinary standard.

It is, therefore, obvious that, so far as our analyses go, they bear out, in every detail, all that Chittenden has contended for, *viz.* :—the feasibility of maintaining the body in a condition of nitrogenous equilibrium over long periods of time on a diet whose proteid or nitrogen value is one-third of that usually accepted as necessary for the needs of the system. Regarding the people with whom we dealt this low proteid intake is the ordinary amount present in the average diet of the whole population ; on this amount they subsist during all the years of their life.

The diet of the native population of Bengal meets Von Noorden's criticism [1] of Chittenden's work—that it is almost impossible in ordinary life to arrange a diet with so low a proteid content, that will not prove insufficient and unsuitable. We shall have occasion later to present analyses of the different food-stuffs ; at present, all we need say is that it is the diet of the masses and is not only inexpensive but agreeable though somewhat monotonous in character.

While this and much more might be said corroborating most of the results obtained by Chittenden we have shown sufficiently that the Bengali is able to maintain the total proteid store of his organism unaltered in amount on a nitrogenous supply that would be much below the amount decomposed during starvation.

We shall now pass to the consideration of the evidence that this minimum amount of proteid is amply sufficient for the maintenance of the body in a perfect condition of health and physical vigour. In this examination we shall deal first with the evidence obtained from students and servants of the Colleges in Calcutta.

II.—The evidence from physical development.

(*a*) *The body-weight.*—From the records of over 2,500 observations on the weight of Bengali students we find the average to be just under 52 kilos. This is very slightly higher than the average weight of the Bengali as worked out from the Bengal Jail statistics by Major Buchanan, I.M.S.[2] From a collection of 28,863 weights and heights of prisoners in Bengal Jails Major Buchanan obtained an average of from 110—112 lbs. or from 50 to 50½ kilos. We shall not, therefore, be much in error if we take the average weight of the Bengali—student or otherwise—at 52 kilos. which is probably slightly over the mark rather than under.

How does this average compare with the average European?

(1) Von Noorden.—The Physiology of Metabolism, 1907.

(2) Buchanan.—Manual of Jail Hygiene, 1901.

From the statistics at our disposal, collected from many different sources, the average weight of the healthy adult male European is about 70 kilos. Quetelet's[1] tables, however, give a somewhat lower average, *viz.*, about 66 kilos. Taking the mean of these figures there is a difference of from 22 to 30 per cent. in favour of the European. In other words, we may say that the average Bengali weighs about 25 per cent. less than the average European.

How does this fact modify the food requirements of the Bengali?

Von Noorden states—" Although both exchange and need are lower in persons of light weight, nevertheless the total individual combustion does not fall in mathematical proportion to the decrease in weight, but by far smaller quantities. The minimal metabolism in children from 12—14 years old does not markedly differ from that of adults." We could not, therefore, expect the Bengali to be properly nourished on a diet 25 per cent. less in amount than the minimal diet necessary for the European. If this be true for the food in general it will be doubly so for the most important constituent of the food—the nitrogenous element. When we find, therefore, his average proteid intake from 60—70 per cent. less than that of the average European we may well ask the question, is the lower average body-weight of the Bengali not the direct consequence of a diet—poor in nitrogen and muscle-forming properties—barely sufficient to meet the physiological needs of the body? As we shall show in connection with the diets of Bengal, the ordinary food of the people contains very abundant quantities of carbohydrate; but neither fat nor carbohydrate go to form "flesh" or to build up any of the true nitrogenous tissues.

That the lower standard of body-weight is not the cause of the low proteid intake is evident from what has been stated above with regard to boys of 12—14 years of age, and also by the fact that the Bengali is not sprung from an under-sized race; his stature and the general build of body-frame compares very favourably with that of Europeans. On the other hand the spareness and very deficient muscular development of the working coolie form a striking contrast to the average European labourer.

While we cannot state that a high average body-weight is the all-important criterion of physical fitness or power of resisting disease, other things being equal, it will be generally admitted that good muscular development is a desideratum in the condition of a people. If this were not the case the usual rules and examination of the physical fitness of recruits for all services where stamina and strength are required would have to be completely altered. In this connection it has also been observed that a close relationship exists between the physical and moral development of men; in fact any lowering of the physical

(1) Quetelet.—Anthropometrie, 1870.

means a lowering of the moral standard of recruits[1]. With a low standard of physical development we are apt to get recruits not only small, but unsteady, wanting in mental ballast as well as in physical strength.

(*b*) *The Height.*—The average height of the adult male European according to Quetelet's tables is 5′-5″ to 5′-6″.

From observations on the height of the same Bengali students quoted under body-weight we find the average works out to be practically identical with Quetelet's, *viz.*, 5′-5½″. Buchanan, from the analysis of his collection of 28,863 heights of prisoners, would place the average height slightly under the above figures, *viz.*, about 5′-4″.

The student series we examined and quote were for the great part entering Government service and were perhaps slightly above the average in height and weight.

(*c*) *The circumference of the chest.*—The chest measurement furnishes a very good idea of the state of development and is made use of in every country in the physical examination of recruits. A certain minimum girth of chest is insisted on; for the ordinary line regiments of the British army this minimum is 33″, but is much above this figure for special regiments or brigades.

The average chest measurement of our series of Bengali students works out to be just below the minimum—33″—for admission to the army. In this comparison it must be remembered that with the height of 5′-5½″ a chest girth well above the mere minimum would be looked for in a desirable recruit.

By a comparison of the records of the weight, height and chest girth a good knowledge of the general physical development is obtained.

The facts, as we have found them, are—

(*a*) The height, averaging 5′-5″ to 5′-6″, is well up to the standard of Europeans.

(*b*) The weight, averaging from 50 to 52 kilos., is, in round figures, 25 per cent. below the European standard.

(*c*) The chest girth, averaging under 33″, is well below the average European standard.

Sir W. Aitken was the first to point out the importance of the correlation of height, weight and chest measurement in estimating physique, good weight for height being of first importance. Several rules have been laid down for guidance in the examination of physical fitness. One formula, which seems to us to demand much too high an average weight, is that up to 5′-7″ thrice the height in inches ought to be about the weight in pounds; this would mean that the average European 5½′ in height should weigh 198 pounds and the average Bengali only a few pounds less.

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(1) *Cf.* Notter and Firth.—Theory and Practice of Hygiene.

Another common rule is " normally developed individuals weigh as many kilos. as their length measures in centimètres after subtracting the first metre" (Landois). This works out very accurately for the average height and weight of Europeans—Europeans 168 c.m. in height should weigh 68 kilos. When we come, however, to apply it to Bengalis, whose average height we have shown to be $5\frac{1}{2}'$ or 165 c.m., we find that the average weight should not be less than 65 to 67 kilos. His actual weight comes far short of this standard, by so much, as we have already seen, as 25 per cent.

From the evidence put forward of the physical development of the Bengali we may fairly come to the conclusion that, on the average, he does not reach the same standard of general physique as is attained by races of European origin; and yet from the evidence we can find no cause inherent in the Bengali as a race for this deficiency; on the contrary, we consider that there may be a very close relationship between the lower physical development of this people and the meagre proteid constituent of the diet on which they subsist.

III.—The evidence from the changes in the blood.

We have already dealt to some extent with the changes found in the blood of the Bengali; Table IX gives the results we have obtained from the analyses carried out.

The more important differences in the chemical composition of the blood are closely connected with the deficiency in the percentage of the floating proteids of the plasma and the low hæmoglobin value of the red blood corpuscle.

Further changes occur in the increased salinity of the blood, lessened coagulation-time, and an increased alkalinity.

[Measured by Wright's method of titration of the serum against diluted normal sulphuric acid with a litmus indicator, there is a distinctly higher degree of alkalinity present than is found in the European.]

The lower level of the pressure of the blood in the arteries is also a point of importance. This will be obvious when we recall the condition of the blood in regard to its hæmoglobin value. We have in the blood of the Bengali a reduction, compared with the average European, of up to 25 per cent. in respect to its hæmoglobin, and with this 25 per cent. decrease in its oxygen-carrying capacity we have, at the same time, the pressure at which it flows in the vessels on a much lower scale than in the European.

The effects of these conditions must be to modify very markedly the physiological requirements of nutrition, and to a considerable extent affect the growth, power of muscular contraction and general metabolism of the individuals of such a community.

From the evidence of differences in the chemical composition of the blood enumerated above it may be fairly deduced that the diet—poor in nitrogen—is the cause of the changes. The blood in chronic underfeeding does not as a rule show any very great variations in composition, as it is able to maintain its composition more or less normal even under very adverse circumstances; but the changes that do occur are all of the same type as we have shown are to be found in the blood of the Bengali. Von Hoesslin states that chronic underfeeding influences the total volume of the blood, as well as the mass of all the tissues, and produces individuals who are poorly supplied with blood, fat and muscle.

We may, therefore, conclude that, so far as the evidence obtained from the blood is concerned, the Bengali falls short of the standard of the European in this respect also. His nitrogenous tissues are not given the option of drawing their nutritive material from so rich a source, nor have they the same opportunity of obtaining as free a supply of the all-important life-sustaining oxygen. There is no deficiency in the absolute number of the red and white cells of the blood; but more or less similar conditions have been found in the blood of the several professional fasters during the periods of their fast. This, as far as one can say, would appear to be an effort on the part of the cell-forming tissues to maintain the composition of the blood as nearly normal as possible—in this way attempting to make up for the deficiency in hæmoglobin and proteid elements. The increased salinity of the blood, which we hold is ever an accompanying feature of anæmia, is present also in the anæmia of the Bengali and is probably the explanation of the increase in the coagulability, alkalinity and specific gravity. How far these different conditions may be explained by an inspissation of the blood—an oligæmic rather than an anæmic condition—is a question that cannot at present be decided.

While it is impossible to state dogmatically that these different factors are due to the insufficient supply of proteid in the food it would appear to be the most plausible, and, as far as the facts go, the only explanation.

We think we are justified in saying that a people, on a diet containing only 37·50 grammes of proteid, live in a more or less chronic state of nitrogenous starvation leading to a loss of body-fat and tissue-proteid with the inevitable result of loss of vigour and strength and a comparatively low capacity for prolonged or sustained muscular effort. We shall have further evidence to produce with regard to the comparative strength and power of performing work of the European and the Bengali; at present it will be sufficient to say that the latter in this respect falls far short of the former—up to, in many instances, as much as from 60 per cent. to 75 per cent. This is not due to any deficiency in the energy-producing carbohydrates and fats, for, as we shall show later, their diet is very rich in the carbohydrate element. We hold, on the other hand, that it is due to a lack of

muscular development and to the lower condition of vitality that must follow from the presence of a composition of the blood exhibiting the lower physiological limits of such necessary constituents as hæmoglobin and floating proteids of the plasma combined with a lower scale of arterial pressure.

All these factors react not only on the muscular tissues but affect every tissue of the body, and particularly the delicate mechanism of the central nervous system.

Mosso's work has taught us that fatigue has much more to do with changes in the central nervous system than with mere fatigue of muscle-substance due either to accumulation of waste-products or consumption of the reserve of energy-producing material. It would, therefore, appear that in a condition in which the metabolic chemical changes of the central nervous system are kept continually on a low level—as in the Bengali—fatigue will be more easily and readily produced. Such, indeed, is in accordance with our everyday experience and such we believe to be an important factor in the causation of the lack of energy and vigour which is characteristic of the race.

IV.—The evidence obtained from the Nitrogen balance in Bengalis.

In order to be in a position to measure the proteid intake of the different persons investigated, a large number of the different kinds of food-stuffs had first to be analysed.

In carrying out this part of the work samples of each different food material were obtained from the reserve store of articles actually used as food. The percentage of each proximate principle was then determined; the following table gives the average results of the estimations. Analyses published by other authorities are added for comparison :—

Table X.

Food-stuff.	Proteid.	Carbohydrate.	Fat.	Ash and minerals.	Authority.
Rice	6·39	83·30	·15	·76	Med. Coll., Cal.
	6·94	77·61	·51	·53	Blythe.
	7·30	78·30	·60	1·00	Church.
Amount of nitrogenous matter varies from 3% — 75°/₀ Notter and Firth.					

Table X—*contd.*

Food-stuff.	Proteid.	Carbohydrate.	Fat.	Ash and minerals.	Authority.
Atta	11·50	67·10	2·90	3·85	Med. Coll., Cal.
	12·04	68·65	1·85	4·00	Notter and Firth.
	12·35	67·91	1·75	4·34	König.
Chana	19·69	56·20	3·95	5·66	Med. Coll., Cal.
	21·70	59·00	4·20	4·70	Church.
Arar Dhall (Husked) .	19·86	57·30	3·20	8·34	Med. Coll., Cal.
	17·10	55·70	2·60	12·20	Church.
Masur Dhall. . .	23·25	59·40	2·70	2·55	Med. Coll., Cal.
	24·81	54·78	1·85	6·09	Blythe.
Maize	9·50	70·70	3·60	3·70	Church.
	9·85	68·41	4·62	4·00	König.
Suttoo	25·46	57·35	1·83	4·68	Med. Coll., Cal.
Molasses . . .	...	69·70	...	6·90	Blythe.
Potatoes . . .	1·79	20·56	·16	1·72	König.
Cabbage . . .	5·00	7·80	·50	1·20	Notter and Firth.
Mustard oil . . .	...	...	99·78	...	Med. Coll., Cal.
Goat's flesh . . .	24·06	...	2·50	1·10	Do.
Fish (Tank) . . .	17·50	...	7·14	...	Do.
	18·10	...	2·90	...	Do.
Milk (Bazar). . .	2·12	...	1·92	...	Do.
Vegetables: cabbage, carrots, turnips, spinach, cauliflower.	2·05	5·33	·34	1·05	Med. Coll., Cal. and various authorities.

We shall now proceed to a consideration of what is to be learned regarding the metabolism of the Bengali from investigations on certain individuals in whom a record of the total nitrogenous intake and output was carefully preserved. These fall into two sets of experiments—the first consist of observations on two of the Medical Assistants of the department. These men were actually engaged in the investigation and were keenly interested in obtaining accurate data. They kept an absolutely correct record of every particle of food eaten. Samples were analysed each day and the total nitrogen of their diet estimated. Owing to

accidental circumstances the investigations had to be dropped after the fourth day; but, as the results are of importance regarding the minimal proteid intake necessary for nitrogenous equilibrium, we reproduce them in Table XI.

This table is of interest from another point of view as, we believe, it is the first time a nitrogen balance sheet has been worked out in India:—

Table XI.

No.	Weight. Kilos.	Nitrogen intake.	Urine in C. Cs.	Sp. Gr.	Nitrogen in Urine.	Nitrogen in Fæces.	Freezing-point of Urine in C°.	Chlorides of Urine in grms.
1 . .	61·81	7·81	1570	1013	8·93	1·38	—1·25	17·56
	61·40	9·46	1490	1011	5·73	1·54	—1·14	16·68
	61·62	7·81	1370	1013	5·91	1·61	—1·24	17·81
	61·62	9·46	1005	1017	6·33	2·31	—1·48	13·16
2 . .	50	10·56	1980	1008	6·90	2·31	— ·92	14·65
	50	10·56	2670	1009	8·72	1·82	—1·00	22·69
	50·5	10·56	1830	1012	7·68	1·28	—1·24	19·21
	50·5	10·56	3090	1010	10·39	2·63	—1·10	29·35

No. 1.—Nitrogen intake during four days under observation. =34·54 grammes.

Nitrogen output during four days under observation. =33·74 „ {Urine 26·90 grmms. Fæces 6·84 „

Nitrogen balance for the four days. = +0·80 „

No. 2.—Nitrogen intake during four days under observation. =42·24 „

Nitrogen output during four days under observation. =41·73 „ {Urine 33·69 „ Fæces 8·04 „

Nitrogen balance for the four days. = +0·51 „

While these observations were not of sufficient duration to provide a complete standard for comparison, they afford very exact information, and it will be instructive to analyse the results in the light of the knowledge already obtained from the two hundred observations on students and servants.

The amount of nitrogen metabolised during the four days by No. 1 was 26·90 grms., or an average daily amount of 6·72 grms. His average body-weight being 61·50 kilos; we find this is equivalent to the metabolism of 0·109 grm. of nitrogen per kilo. of body-weight. Translating this into terms of proteid it

means the daily metabolism of only 0·681 grm. per kilo. of body-weight—an amount even below the average we obtained for students and servants.

Yet with this very small intake of proteid there was, as shown by the plus nitrogen balance, a retention during the four days of 0·80 grm. of nitrogen; so that not only was the amount of proteid food consumed quite adequate to meet the demands of the body, but the latter was able to store up 5 grms. of proteid during the period of observation.

Chittenden states that 0·12 grm. of nitrogen per kilo. of body-weight is quite sufficient to meet all proteid requirements. As will be evident the above results bear out his contention. This particular individual was well nourished, muscular, with no excessive amount of fat.

A point of considerable importance brought out by the analyses is the large quantity of nitrogen in the fæces. During the four days no less than 25·42 per cent. of the total nitrogen of the food re-appeared in the fæces, having passed through unabsorbed. This is a very high percentage of waste; even in an entirely vegetable diet, as understood by Europeans, usually 85 per cent. at least of the proteid is absorbed. The diet in the present case consisted largely of rice and dhall. We shall have more to say with regard to fæcal nitrogen when we discuss the second series of experiments.

No. 2 of the above table is a particularly thin man, poor in muscular development and with practically no fat.

In his case the total intake of nitrogen during the four days was 42·24 grammes, the quantity of this that underwent metabolism being 33·69 grammes. This means for a body-weight of 50·50 kilos. the metabolism of 0·166 grm. of nitrogen, or putting it in terms of proteid, the metabolism of 1·037 grammes of proteid per kilo. of body-weight.

This is a very much higher amount than was the case either in No. 1 or in the series of two hundred students and servants analysed above, and it is very much higher than the quantity considered by Chittenden sufficient to cover all the proteid needs of the body.

We may draw attention to the fact that although No. 2 assimilated no less than 6·79 grammes of nitrogen or 42·43 grammes of proteid more than No. 1 during the four days, yet the nitrogen balance shows that No. 1 retained actually more of his proteid than No. 2—the former had a plus balance of 0·80 grm. nitrogen, while the latter only shows 0·51 grm. nitrogen. This is a very g od illustration of the first great law of metabolism that, within certain limits—the limits of nitrogenous equilibrium—the body lives up to its income of nitrogen; the law may be formulated thus: "Consumption of proteid is largely determined by supply" (Stewart).

Again, we find a large amount of nitrogen in the fæces, in this instance 23·86

per cent. of the total proteid intake re-appeared in the stools, never having been assimilated and therefore can only be looked on as so much waste. The diet of No. 2 also largely consisted of rice and dhall.

The second set of investigations was carried out on prisoners. In order to facilitate the work and to obtain some idea of the constitution and nature of the different scales of diet laid down for prisoners a table was prepared showing the quantities of the several proximate principles of the diets in grammes.

This is reproduced in Table XII.

As will be at once evident, these diet scales are exceedingly liberal compared with those we have discussed so far.

The proteid element in some instances almost reaches Voit's standard and is far superior in quantity to the proteid element in the average diet of the great majority of the population of the province.

Table XII.

Diet No.	Proximate Principles.	Rice.	Wheat Flour.	Maize.	Suttoo.	Molasses.	Dhall.	Vegetables,	Mustard Oil.	Value of diet in grammes.
I	Proteid	46·39	...	...	...	...	33·79	3·48	...	84·66
	Carbohydrate	613·00	...	...	...	...	67·46	9·06	...	719·52
	Fat	1·10	...	...	...	...	5·44	1·58	17·35	24·47
II	Proteid	39·85	10·86	...	...	...	33·79	3·48	..	87·98
	Carbohydrate	519·54	63·40	...	...	...	97·46	9·06	...	689·46
	Fat	·93	2·74	...	..	...	5·44	1·58	17·35	27·04
III	Proteid	39·85	...	...	21·65	...	33·69	3·48	...	98·77
	Carbohydrate	519·54	...	..	48·77	19·75	97·46	9·06	...	694·58
	Fat	·93	...	...	1·55	...	5·54	1·58	17·35	25·85
IV	Proteid	28·98	...	35·90	...	...	33·79	3·48	...	102·15
	Carbohydrate	377·84	...	232·70	...	...	97·46	9.06	...	717·09
	Fat	2·67	...	17·00	...	...	5·44	1·58	17·35	43·04
V	Proteid	28·98	32·60	...	...	...	33·79	3·48	...	98·85
	Carbohydrate	377·84	190·22	...	...	...	97·46	9·06	...	674·58
	Fat	2·67	8·22	...	...	...	5·44	1·58	17 35	34·26
VI	Proteid	21·74	42·47	...	...	...	33·69	3·48	...	101·48
	Carbohydrate	283·38	253·53	...	...	...	97·46	9·06	...	643·43
	Fat	2·21	10·96	...	...	...	5·44	1·58	17·35	36·54
VII	Proteid	21·74	32·60	...	21·65	...	33·79	3·48	...	113·26
	Carbohydrate	283·38	190·22	...	48·77	19·75	97·46	9·06	...	648·62
	Fat	2·21	8·22	...	1·55	...	5·44	1·58	17·35	35·35
VIII	Proteid	21·74	...	...	21·65	...	33·79	3·48	...	116·36
	Carbohydrate	283·38	...	...	48·77	19·75	97·46	9·06	...	688·15
	Fat	2·21	...	...	1·55	...	5·44	1·58	7·35	44·13

Average fuel value of above diets— 3,380 Calories.

[*A.—Gramineæ.*—(1) Oryza Sativa, Linn., RICE.

Hab.—Throughout India, wild and cultivated.

Use.—Rice is the staple-food of the inhabitants of Bengal, many parts of Madras, Burma and the Western Coast of India, but not of the Central or Northern parts of the country, where wheat and millet are largely used.

(2) Zea Mays, Linn., MAIZE.

Vernacular.—Makkai, Bhuta, Janar.

Uses.—Used as a food for man and beast.

(3) Triticum Sativum, Lam., WHEAT.

Hab.—The Euphrates region. Cultivated in North-West India, the Central Provinces, and Bombay.

Uses.—It is one of the most important of the cereals and largely used for food.

B.—Leguminosæ.—(1) Cicer Arietinum, Linn., COMMON CHICKPEA.

Vernacular.—Chana, But.

Uses.—This pulse is the Cicer of the Romans. In India the seeds form one of the favourite pulses being eaten raw or cooked in a variety of ways. The flour is also much used as a cosmetic and in cookery.

(2) Erbum Lens, Linn., MASURA DHALL.

(3) Cajanus Indicus. ARAR DHALL.

(4) Phaseolus Mungo, Linn., MUNG DHALL.

These are the common forms made use of in Bengal. As is wellknown, another variety—(5) Lathyrus Sativus,—made use of as an article of diet, is capable of producing toxic symptoms. The condition is known as *lathyrismus* and at one time affected nearly four per cent. of the population of one district in Bengal.

ATTA is the flour obtained from grinding wheat.

SUTTOO is fried chana or chickpea ground to flour.]

These diets, however, are all entirely of a vegetable nature and practically all the nitrogenous element is derived from rice and dhall. With an ordinary vegetable diet we expect an average of about 85 per cent. of the proteid to be absorbed, but, as will be apparent from our observations on prisoners and others, a much lower percentage is absorbed from diets of the above type. For the present we are unable to state dogmatically what the cause of this large amount of unabsorbed nitrogenous material in the fæces is, but from the few observations made we consider it mainly to be ascribed to the dhall and more particularly to dhall of a certain type. The whole question of the large nitrogenous residue characteristic of Bengalis is an important one and requires careful investigation. A splendid opportunity for the growth of micro-oganisms with its attendant intestinal putrefaction and toxæmia is provided, predisposing to numerous pathological conditions such, for instance, as septic ulceration of the

gums, intestinal catarrh and diarrhœa, dysentery and anæmia. These are all exceedingly common disorders met with in the outpatient department of a general hospital.

Large quantities of rice have to be given in order to obtain the necessary amount of proteid; this leads to an excessive intake of carbohydrate. Compared with Voit's diet containing 500 grammes or Ranke's containing 240 grammes of carbohydrate, the food provided for prisoners shows a great abundance of the carbohydrate element. On the other hand the fat element is deficient; the deficiency, however, is more than made up by the liberal carbohydrate allowance.

The excess of carbohydrate over ordinary bodily requirements may be made use of as a proteid-sparer, but in order to spare even a small quantity of proteid a large amount of carbohydrate is required. Further, so long as sufficient proteid is being assimilated to maintain nitrogenous equilibrium it is quite unnecessary to add a large amount of carbohydrates to a diet in order to spare the proteid material.

We may conclude from an examination of the above types of diet that, simply as a means of providing fuel for the system, there is a very heavy wastage, while the constant fermentation and putrefaction made possible by the copious nitrogenous residue in the alimentary canal must form a source of chronic irritation to the mucous membrane of the bowel, predisposing to intestinal catarrh, diarrhœa, etc. At the same time the products of the putrefactive micro-organisms on absorption lower the general vitality, causing anæmia, toxæmia, and many other symptoms of ill-health. We are very much inclined to believe that the diet of the Bengali, prisoner or other, bears a close relationship to the exceeding prevalence of intestinal troubles among the population of this province.

In carrying out the investigations on prisoners, four healthy men of above the average weight who had been sentenced to hard labour were selected from a number of volunteers. Arrangements were made by the Superintendent of the Jail—Major Mulvany, I.M.S.—for obtaining an accurate record of the total intake of food and for collection of the excreta, both urine and fæces. The diet for these four prisoners was prepared separately, each ingredient having previously been weighed, the quantity of each separate item of the food that remained uneaten was weighed and its value in nitrogen deducted from the total nitrogenous value of that day's diet.

Similarly, with regard to the excreta; special arrangements were made for these prisoners, the urine and fæces were collected separately, their quantity measured and weighed and sent for examination.

The enquiry began on the 13th February 1907 and was completed on the

25th March 1907. Daily analyses (Sundays excepted) were carried out on 35 days for each prisoner.

The points noted were:—Caste, age, weight, amount of nitrogen in food, quantity of urine excreted, specific gravity of urine, urea in terms of nitrogen, nitrogen in fæces, freezing-point of urine, the total chlorides of urine and work done.

The nitrogen of the urine was not specially estimated, as it was considered that with a knowledge of the total nitrogen intake and the output of fæcal nitrogen we obtained by subtracting the latter from the former an absolute measure of the amount of proteid absorbed and assimilated from the food. However, as a check on this, besides the ordinary Kjeldahl's control, we made an estimation of the nitrogen execreted in the form of urea each day.

As there is nothing to be gained by giving a complete list of each day's analyses we reproduce in tabular form the observations made on six consecutive days at the beginning and end of the period of examination. These 48 analyses are quite sufficient to show everything of importance that is to be learned with regard to the metabolism of these four prisoners. Table XIII gives the information referred to.

We have already discussed to some extent the scales of diet laid down for prisoners. They show, compared with the usual standards, a slight deficiency in proteid, an excessive carbohydrate element and a low fat intake.

Further, beside the salt present in the different materials composing the diet, there was added during cooking up to, in most instances, an ounce of sodium chloride. These men had, therefore, no option with regard to the amount of salt they consumed. We may take it that the quantity of salt present in the daily diet was not less than from 30 to 32 grammes.

So far as we are specially concerned the nitrogen and salt of the diet are the most interesting subjects. The carbohydrate and fat elements may be accepted as being amply sufficient to meet all demands for heat and energy-production.

Let us now examine the table in more detail. The nitrogen intake varies round a standard of 14·40 grammes per day. From analyses of the actual ingredients of the food for these men we found the nitrogenous intake was made up in the following way:—

From	rice	was derived	47·39	grammes	of	proteid.
„	masur dhall	„	19·78	„	„	„
„	arar	„ „	16·89	„	„	„
„	vegetables	„	3·48	„	„	„
„	fish	„	2·48 or 2·69	grammes	„	

This totals up to an intake of 90·02 or 90·71 grammes of proteid daily; or expressed in terms of nitrogen is 14·40 or 14·51 grammes as the case may be.

Table XIII.

Day.	No.	Caste.	Age.	Weight.	Amount of nitrogen in food.	Urine in C. Cs.	Specific Gravity.	Urea in nitrogen.	Nitrogen in fæces.	Freezing-point—°C.	Chlorides.	Work.	Remarks.
1	4229 A	M	31	123½	14·40	1802	1012	7·98	3·79	1·42	28·48	Hard Labour: expressing 10 seers of mustard-oil daily.	
2	,,	,,		124	14·40	2413	1015	9·57	3·95	1·33	37·64		⅛ oz. Nacl.
3	,,	,,		123	14·40	1675	1013	7·42	3·02	1·30	22·91		
4	,,	,,		122½	14·40	2839	1010	9·45	2·83	1·13	38·04		extra.
5	,,	,,		124	14·40	1958	1016	8·77	4·83	1·42	32·51		,,
6	,,	,,		124½	14·40	2058	1014	8·16	3·97	1·37	32·92		,,
1	7183 A	H	22	135½	14·20	3670	1008	11·13	6·51	·84	33·39	,,	⅛ oz. Nacl.
2	,,	,,		136	14·20	3100	1007	8·67	2·30	·71	20·77		
3	,,	,,		135	13·46	3570	1005	9·16	2·77	·62	19·63		extra.
4	,,	,,		134½	14·61	3280	1006	8·41	3·71	·77	27·88		
5	,,	,,		135	14·40	3305	1006	8·86	3·62	·85	31·73		,,
6	,,	,,		136½	14·40	3420	1010	9·90	6·66	1·18	46·17		,,
1	9614 A	M	28	128	14·60	1802	1018	7·77	4·98	1·75	35·85	,,	⅛ oz. Nacl.
2	,,	,,		128	14·40	2810	1010	11·80	2·39	·96	32·87		
3	,,	,,		128½	14·60	1830	1018	9·39	3·31	1·81	37·33		extra.
4	,,	,,		128	14·40	1916	1020	10·32	3·31	2·03	35·44		
5	,,	,,		129	14·40	1690	1018	10·25	2·12	1·83	36·67		each day.
6	,,	,,		128	14·40	2839	1011	10·26	4·35	1·35	35·48		
1	6110 B	H	35	120	14·40	2058	1014	7·92	4·97	1·37	27·78	,,	⅛ oz. Nacl.
2	,,	,,		119½	14·40	3037	1007	7·36	*Nil*	·92	29·45		
3	,,	,,		120	14·60	2370	1011	9·95	6·83	1·12	29·86		extra.
4	,,	,,		118	14·40	2583	1011	10·24	4·26	1·23	30·47		,,
5	,,	,,		118	14·40	2867	1015	11·37	1·23	1·48	48·73		,,
6	,,	,,		119	14·40	3094	1010	10·46	4·06	1·13	35·58		

Weight is given in grammes throughout. The prisoners' weight in lbs. Nitrogen of food and fæces was estimated by Kjeldahl's method. The average amount of salt in the diet was 30 grammes (*circa*).

Table XIII—*continued.*

Day.	No.	Caste.	Age.	Weight.	Amount of nitrogen in food.	Urine in C. Cs.	Special Gravity.	Urea in nitrogen.	Nitrogen in fæces.	Freezing-point —°C.	Chlorides.	Work.	Remarks.
1	4229 A	M	31	121½	14.40	1973	1013	9·28	3·69	1·40	28·08	Hard Labour.	
2	„	„		123½	14.61	1987	1013	9·57	4·25	1·27	28·84		
3	„	„		123½	14·40	1930	1014	9·02	3·42	1·31	29·30		
4	„	„		122½	14·26	1987	1011	11·46	2·68	1·32	25·84		
5	„	„		124	14.40	1873	1013	8·77	4·01	1·37	29·51		
6	„	„		124½	14·60	1930	1010	10·76	3·27	1·10	22·92		
1	7183 A	H	22	134½	14·11	3208	1013	8·34	3·31	1·26	51·00	„	⅛ oz. Nacl extra each day.
2	„	„		135½	14·61	3577	1009	10·26	3·46	·91	33·26		
3	„	„		134	14·40	2503	1013	10·24	2·58	1·04	28·92		
4	„	„		135½	14·40	3875	1007	10·30	1·81	·87	36·03		
5	„	„		136	14·61	3350	1009	11·05	2·23	·95	38·09		
6	„	„		135	13·46	3062	1008	9·34	4·20	1·08	36·25		
1	8614 A	M	28	131	14·40	2190	1008	9·65	4·63	1.07	39·87	„	„
2	„	„		130½	14·61	2660	1012	6·82	2·58	1.23	43·35		
3	„	„		130	14·40	2360	1011	6·85	3·49	1.20	31·86		
4	„	„		130	13·60	3080	1013	10·04	4·91	1.28	48·36		
5	„	„		130	14·80	2590	1010	12·08	4·23	1.09	27·71		
6	„	„		129	14·40	2040	1012	10·61	4·83	1.28	23·86		
1	6110 B	H	35	118	14·40	1731	1010	8·88	7·86	1·08	15·92	„	„
2	„	„		117	14·31	2455	1013	11·01	2·71	1·32	31·66		
3	„	„		116½	14·61	1864	1010	10·41	1·92	1·38	22·32		
4	„	„		116½	14·40	2441	1014	9·52	3·41	1·32	34·41		
5	„	„		116½	14·40	2001	1014	9·05	4·50	1·34	27·80		
6	„	„		118	14·04	1802	1014	8.19	2·83	1·35	27·22		

Practically speaking the diet is vegetable in character, only 2·48 or at most 2·69 grammes proteid coming from flesh in the form of fish. More than half the proteid is provided in the form of rice and the great majority of the remainder in the form of dhall.

It will be evident from the results we obtained in the case of students, servants and assistants that this amount of proteid is quite sufficient to maintain the body in a condition of nitrogenous equilibrium. Whether maintenance of nitrogenous equilibrium on a low proteid intake and maintenance of the body in an ideal condition of health and vigour are identical as Chittenden's statements would tend to lead us to believe, is an open question and one on which we have been able to bring a certain amount of evidence to bear. From a quantitative proteid intake standpoint the diet may be said to have little interest; but it is very different when we come to examine its real value, *i.e.*, the amount of proteid absorbable and of actual service in the system. In order to show the principal points of importance in connection with the fate of the nitrogen of the food we have drawn up Table XIV. This table covers the same period as Table XIII and is derived from it.

Table XIV.

Individual.	Total nitrogen intake in grms.	Total fæcal nitrogen in grms.	Total nitrogen assimilated in grms.	Per cent. of nitrogen unabsorbed from food.	Per cent. of nitrogen absorbed from food.	Nitrogen excreted as urea in grms.	Per cent. of nitrogen of food excreted as urea.	Per cent. of nitrogen of urine excreted as urea*.
				...	...		...	...
4229 A .	172·07	43·64	128·43	25·36	74·64	108·22	62·88	84·26
7183 A .	170·86	42·16	128·70	24·67	75·33	115·66	67·69	89·86
9614 A .	173·01	46·13	126·88	26·72	73·28	115·84	66·95	91·29
6110 A .	172·76	44·58	128·18	25·86	74·14	114·36	66·19	89·21

[* The percentages of the nitrogen of the urine excreted as urea are slightly too high; no notice is taken of the nitrogen that is assimilated and eliminated in the sweat, epithelial scales, etc. The total amount of this is, however, very trifling and may be neglected.]

It may be taken that these four men were in a condition of nitrogenous equilibrium and that the amount of proteid absorbed was sufficient to meet all nitrogenous requirements; as evidence of this we have the fact that they were able to carry on the work provided—"hard labour"—without distress or any loss of body-weight.

The average intake of nitrogen works out at 14·34 grammes per day, of which 10·67 grammes were absorbed. The weight of these men on the average was

57 kilos so that $\frac{10.69}{57} = 0.185$ gramme, that is, each man had the metabolism of 0·185 gramme of nitrogen per kilo of body-weight daily. Compared with Chittenden's statement of the quantity he considers necessary, or our own figures obtained from a study of Bengali students and others, this is a very liberal allowance. On the other hand, when we examine the columns in Table XIV showing the percentage of the absorbable to the non-absorbable, it is evident that the diet is an inferior one. Over the series of analyses recorded no less than 25·52 per cent. of the proteid of the food passes out unchanged. This result is in marked contrast to what Chittenden obtained in different experiments on students, scientific men and soldiers; in all his records the fæcal nitrogen was exceedingly small in amount. To this he attaches the greatest importance and, in fact, makes it one of the principal arguments in favour of strict moderation of proteid intake, contending that with a small nitrogenous residue the opportunity afforded for intestinal putrefaction and fæcal intoxication is kept at a minimum. If this view is sound and worthy of credence, and we believe it to be so, what can be said about the diets presented and discussed above? They are one and all bad in every respect, and particularly bad in that the large waste in the alimentary canal allows excessive micro-organismal development and formation of toxic compounds. As we already have had occasion to point out, this must assuredly be a factor in the prevalence of intestinal disorders and in the causation of certain diseases. So much is this the case that an experienced Jail officer states that it is one of the rarest of novelties to discover a prisoner who passes a solid stool.

From an economical standpoint alone the large waste in food material is worthy of consideration and investigation. What part of the diet is principally to blame? We have made some investigations and collected evidence that would appear to inculpate the dhall; they are not sufficient, however, to base a definite opinion on. It is well known that, even among those accustomed to dhall and of course much more so with Europeans, if a small amount of dhall more than usual be partaken of, diarrhœa and intestinal troubles are apt to ensue. Further, in connection with the fluid condition of the stool characteristic of the dhall-eating Bengali we can state from personal experience that its fluidity is not due to rice,—the Chinese and Japanese are great rice-eating people, yet their stools are not watery but well-formed. Dysentery may be said to be comparatively rare in the provinces of India where the diet of the population does not mainly consist of rice and dhall, whereas in Bengal, both in the Jails and elsewhere, dysentery is very prevalent.

An enquiry into this matter is urgently necessary and might materially assist in eradicating some of the most serious and fatal afflictions from the province of Bengal.

The last point to which we wish to refer is the salt elimination of the urine in the form of chlorides.

The actual amount of salt added to the food of these men was up to, in most instances, 28 grammes daily ; this was in addition to the salt already present in the composition of the different food materials. From a glance at Table XIII it is apparent that large quantities of chlorides were eliminated in the urine. On the average, for the daily analyses shown, the excretion of chlorides comes to 32·30 grammes. We have already discussed at some length the evidence for an increased physiological demand for sodium chloride when the diet is largely vegetable, and we have shown that excessive quantities of salt are not generally made use of by the Bengali. The reason of this is that rice forms the great bulk of the food of the Bengali and rice contains comparatively little potassium salts; so that, accepting Bunge's explanation that the increased demand for salt with a vegetable diet depends on the effects of the contained potassium salts causing an increased elimination of sodium and chlorine in the urine, there is no urgent reason with diets of the above type for a large addition of salt.

Physiologically the presence of from 4 to 6 grammes of salt in the daily diet is sufficient protection against a loss of chlorine from the blood and tissues. With a purely vegetable diet, as in the case of our figures for students, etc., we found the average amount excreted daily was under 10 grammes. With regard to these four prisoners the excretion was more than three times as great as in other Bengalis, and, as will be evident, it corresponded very closely with the intake.

What is the effect of this excessive ingestion of salt ? Straub states when the salt intake reaches 0·6 to 1·1 gramme per kilo of body-weight diuresis and augmented nitrogenous metabolism sets in. In the prisoners under observation Straub's lower limit was exceeded, and, as will be apparent from the column of Table XIII giving the quantity of urine excreted, diuresis was a marked feature in every instance where the salt intake was high.

This is in accordance with what would be expected and with common experience. Salt taken in excess must either be eliminated or retained within the system ; whether eliminated or retained water must be imbibed in sufficient quantity to form an isotonic solution.

If the kidneys are normal this excess of salt and water is quickly got rid of in the urine; but, as the kidneys are only able to excrete a dilute saline solution, large quantities of water are necessary in order to eliminate the excess of salt—hence the thirst and diuresis.

In an ordinary healthy individual with a normal salt intake and on whom salt equilibrium is established, if the ingestion of salt be greatly increased

there will be at once a large increase in the amount of salt eliminated in the urine; but the output will not be quite equal to the increased intake, so that some has been retained. With this retention there must be also a retention of fluids to keep the salt in solution; in this way there will be an increase in the body-weight in proportion to the degree of salt retention. Later as the system becomes accustomed to the larger salt intake it attains, as it were, a higher level of salt metabolism, all excess of salt above this level being got rid of so that salt equilibrium again becomes established.

We may conclude that there is no justification for the employment of such excessive amounts of salt in the diets of prisoners. Its effects are to increase the work thrown on the kidneys, to increase the salt concentration of the blood and tissues rendering the latter more or less water-logged and to cause thirst and diuresis. In addition there will be a fictitious advance in body-weight due to the retention of fluids by the tissues.

V.—Evidence of the effects of a low proteid intake on the physical development of Bengal Students.

We were fortunate enough to secure the carefully tabulated records for a large number of years of the age, weight, chest-girth and height of the Bengali students attending one of the colleges. The measurements and weights were taken for each year while the particular student was a member of the institution; this was usually four years. We have thus a record showing the age, weight, chest-girth and height, for each of the four years they remained students, of some 568 persons.

We were also able to obtain from the Medical Officer of the College an authentic statement of the diet scale sanctioned for these Bengali students. The value of the diet is shown in detail in Table XV.

Table XV.

Proximate Principles.	Sooji.	Sugar.	Ghee.	Balam Rice.	Dhall.	Mustard Oil.	Salt.	Vegetables.	Potatoes.	Goor Treacle.	Fish.	Mutton.
Proteid	4·89	...	...	28·98	18·07	...	...	1·79	4·08	...	2·57	6·73
Carbohydrate	28·55	42·45	...	363·91	48·66	...	...	4·53	46·64	14·19	...	...
Fat	·76	...	28·27	·65	1·70	37·81	...	·29	·36	...	·41	1·30
Salt	...	...	...	...	...	...	14·19	...	...	...	...	...

Total value.

Proteids	=	67·11	grammes.
Carbohydrate	=	548·73	"
Fat	=	71·55	"
Salt	=	14·19	"

The diet is very much more varied and appetising than is sanctioned for prisoners. The gross amounts of the different constituents are less in quantity—except as regards fat—but, on the other hand, there is not such a close approach to a cereal diet as in the Jail types, about 13 per cent. of the proteid element being obtained from meat.

With regard to the carbohydrate and fat in the diet there is nothing of much interest. It will be readily admitted that these elements are quite adequate to meet the wants of the body in energy and heat-production; in fact, when we consider the climate of Bengal, the question would arise whether the fat was not too abundant for the heat-production necessary in tropical countries.

The gross proteid intake of this diet works out to be 67·11 grammes per day, or an amount very little more than half Voit's standard. We have shown, however, that the waste of proteid is very large with a diet consisting largely of dhall and rice; in the prisoners we found this loss accounted for more than 25 per cent. of the total proteid of the diet. Further, with regard to the remaining proteid, if we accept an absorption of the usual percentage—90 per cent.—we shall be able to calculate the real value of the intake.

The absorbable proteid from the vegetable part of the diet works out at 42·45 grammes and from the animal materials 8·37 grammes. So that the real proteid intake of the diet would appear to be 50·82 grammes and not 67·11 grammes.

This amount, 50·82 grammes, is actually less than half of the 105 grammes of assimilable proteid of Voit's standard diet, and approaches very closely the quantity Chittenden considers amply sufficient.

The average weight of these students was 54 kilos; it would therefore follow that a diet containing 50·82 absorbable proteid affords the metabolism of 0·941 grm. of proteid or expressed in terms of nitrogen the metabolism of 0·148 grm. of nitrogen, per kilo. of body-weight. The quantity of nitrogen per kilo. of body-weight metabolised by Chittenden's three classes was 0·13 grm. per day; these Bengali students had therefore a slightly superior proteid metabolism. On the other hand, the metabolism of the four prisoners examined was on a much higher scale; as will be seen above it rose to an average of 0·185 grm. of nitrogen per kilo. of body-weight, while the investigations on students and servants of the Medical College showed an average metabolism of 0·116 grm. per kilo. of body-weight. In order to make these varying amounts of nitrogenous metabolism for the different classes examined more easily understood we collect them in tabular form.

Table XVI.

Place of observations.	Number.	Average weight kilos.	Daily proteid metabolism (excluding nitrogen of fæces).	Nitrogen per kilo of body-weight grm.	Duration.
A—America,—Chittenden—					
I. Scientific workers . .	5	63·9	47	0·12	6-9 months.
II. Medical corps . .	13	61·5	49	0·13	6 "
III. Athletes . . .	8	70·0	55	0·13	5 "
B—Medical College, Calcutta—					
I. Students and Servants of Medical College . .	44	52	37·50	0·116	Life.
II. Students of another College	568	54	50·82	0·148	Four years.
III. Prisoners . .	4	57	66·81	0·185	Variable.

From the evidence of the physical development and condition of the blood in our first series of observations— on students and servants—we were led to the conclusion that, while the proteid intake was adequate to maintain the system in a condition of nitrogenous equilibrium it was probably insufficient to allow of the attainment of a physique comparable with that of Europeans. With regard to the investigations on prisoners, in all probability the metabolism of an intake of 66·81 grammes of assimilable proteid daily is quite sufficient to meet ordinary physiological wear and tear in adults and to provide a surplus for growth if required.

We shall now examine the evidence regarding the sufficiency or otherwise of the 50·82 grammes assimilable proteid in the diet of our second class of students.

The usual age of entrance into the College was in the 17th or 18th year—a few entered earlier—some under 16 years of age, and a very limited number were up to twenty years old. We may therefore regard these students as being just about the time of life when growth and development would be most active. As they remained, in most cases, four years at the College on the above type of diet, the statistics of the weight, chest-girth and height of each student year by year afford a reliable criterion on which to base an opinion with regard to the amount of physical development that took place while on the diet stated. This in its turn will give us a trustworthy test of the adequacy or otherwise of the diet as a whole and more particularly—the carbohydrate and fatty elements being

admittedly sufficient—will afford us information regarding the physiological minimum of proteid metabolism. What were the actual results?

In making up the following figures we have neglected the last or fourth year completely, as a number of the weighments and measurements for that year were missing.

The facts are as follows :—

(1) There is an increase in the body-weight on the average over the whole series of only 2lbs. in a comparison of the weight on entrance and weight in the third year.

(2) In a comparison of weight on entrance and weight in the third year 42·8 per cent. of the students show a diminution in body-weight; only 15·3 per cent. gained weight continuously during the three years.

(3) In a comparison of weight on entrance and weight in the second year of attendance 55·8 per cent. of the students show a diminution in body-weight.

(4) The chest-girth practically remained stationary.

(5) As would be expected from the age of entrance the large majority—over 80 per cent.—of all the students showed an increase in height ranging from 1½ in. to 2½ in.

In the face of results such as these we can only conclude that the metabolism of 0·148 grm. nitrogen per kilo. of body-weight is not sufficient to meet the nitrogenous needs of the growing Bengali, and in from 30 to 40 per cent. of the 568 examined was insufficient to prevent the loss of formed tissue proteid as the diminution in body-weight would appear to mean. These results bear out in a very marked manner the conclusions we arrived at from a study of the metabolism of the students and servants of the Medical College.

On referring to table XVI it will be seen that Chittenden was able to maintain the individuals of his three different classes in health and vigour with no loss of tissue proteids on a daily proteid metabolism—0·12 and 0·13 grm. of nitrogen per kilo.—actually lower than even that of these students. The explanation of this discrepancy would appear to depend probably on differences in the chemical composition of the proteid molecule in the two cases. More, perhaps, of the proteid products of digestion—although absorbed—being eliminated at once by the kidneys, and never having been of any real service to the body, in the case of diets of the type common in Bengal than is true for the food material made use of in his experiments. Another factor which we believe to have a marked influence on the nitrogenous requirements of the body is growth of the higher proteid-containing tissues. It is evident that when proteid is being stored up in the body in the form of "flesh"—as is the case during infancy and childhood—more will be required in the diet than is necessary when it is only a matter of replacing the loss due to physiological wear and tear. This would go far to

explain the discrepancy above noted as the larger proportion of those of the students who lost weight were below 18 years of age and were therefore in need of a higher proteid intake than provided in the diet. The individuals on whom Chittenden experimented were, on the other hand, all fully matured adults with their total mass of proteid-containing tissues already formed, so that retention on that account was unnecessary; nitrogenous equilibrium could therefore be established on a comparatively lower proteid intake.

It is quite possible that in the construction of tissue-proteid certain groups of molecules are needed and, in order to obtain these, there must seemingly be a wasteful use of proteid food, hence the demand for a large nitrogenous intake during early life. Further, in connection with this subject, facts are beginning to accumulate pointing to the specific nature of the proteid counting for something in nutrition. Chittenden states with regard to the experiments on feeding of dogs: "It is somewhat impressive to note how well dogs thrive on a relatively large amount of vegetable food, provided there is a modicum of animal food added thereto. In other words, these high proteid-consumers are apparently quite able to utilise the vegetable foods, but there is something lacking in such a diet which the body has need of." The grouping of the atoms in the proteid molecule is different when the proteid comes from the animal or from the vegetable kingdom. They yield different decomposition-products or the same products in different proportions so that in absorption and assimilation of the proteid food-stuffs the body has to deal with the various chemical elements. There is thus a distinct possibility, even a probability, that in the vegetable diet of the Bengali certain cleavage products are lacking or only formed in very small proportion, the result of which is that physical development is retarded and, in most instances, the muscular tissues are exceedingly meagre and thin.

To quote Chittenden[1] again: "If we suppose that in the formation of true tissue proteid or the living protoplasm of the cell, certain of these end-products of proteid decomposition are absolutely indispensable, we can easily picture to ourselves a dearth of such building stones in the long continued use of a diet which lacks that particular proteid from which the necessary building stones can be split off in adequate numbers." The conception in this quotation may be applied equally truly to the replacement of old worn-out stones and to the ordinary processes of endogenous or tissue metabolism as to the building up of new tissue proteid.

As an example of a still more inferior type of diet we produce the value in proximate principles of the food-stuffs laid down for students of another college in Bengal. From enquiries we believe the students provide themselves with extra materials—finding the scale sanctioned insufficient.

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(1) Chittenden.—The Nutrition of Man, 1907.

It will be evident that a diet of this type is absolutely inadequate in practically every detail. The amount of absorbable proteid is below what is necessary to maintain nitrogenous equilibrium and the heat value of the diet is very deficient.

Table XVII.

Proximate Principles.	Rice.	Dhall.	Potatoes.	Green Vegetables.	Mustard Oil.	Ghee.	Meat.	Fish.	Total in grammes.
Proteid . .	13·58	8·43	1·81	1·86	...	...	8·06	9·87	43·61
Carbohydrate .	154·88	21·56	19·04	4·83	...	...	...	...	200·31
Fat . . .	·27	·98	·14	·30	22·68	6·80	1·18	1·57	33·92
Salt . . .	...	...	...	...	...	...	...	...	11·34

We have now finished our observations on the metabolism of the Bengali; but, before proceeding to the discussion of other lines of evidence it will not be altogether unprofitable or uninteresting to refer briefly to certain investigations on Anglo-Indian and Eurasian students carried out under exactly similar conditions to those on the two classes of Bengali students.

VI.—The evidence obtained from a study of the metabolism of Anglo-Indian and Eurasian students.

Under this heading we shall discuss the knowledge derived from an analyses of the urine of Anglo-Indian and Eurasian students who were on a known diet; and, in the case of certain other students of the same class a record of whose age, height, weight and chest-girth was recorded for four consecutive years, we shall examine the process of physical development that was observed on a fixed and known scale of diet.

(*a*) Observations on the urine of Anglo-Indian and Eurasian students living on a known diet.

The diet scale laid down for these students—shown on Table XIX—is much more liberal than any of the diets analysed in the case of Bengalis. Further, it will be noticed that the proteid element is derived from various sources, well over half being animal in origin. Although the quantity of proteid falls short of Voit's standard the results of our investigations would go far to prove that the proteid intake was sufficient to meet all the nitrogenous requirements of these students.

Of course it is open for anyone to say that with a larger proteid intake even better results might have been obtained. All the evidence we have

hitherto been able to accumulate would certainly point to the fact that with a diet poorer in nitrogen—particularly in the case of young growing adults—a defective physical development must be expected. We give in tabular form the urine analyses carried out.

Table XVIII.

No.	Quantity in C. Cs.	Sp. Gravity.	Urea in grms.	Total nitrogen in grms.	Freezing-point.	Chlorides in grammes.	No. of consecutive days on which analyses were carried out.
1	1227	1015	16·21	8·55	—1·25°C.	11·82	4
2	941	1019	18·91	9·32	—1·51°C.	12·62	5
3	955	1018	17·87	8·37	—1·55°C.	13·38	5
4	1320	1012	19·80	9·02	—1·11°C.	8·11	5
5	740	1025	19·74	9·52	—2·18°C.	13·70	5
6	1120	1016	19·36	9·23	—1·51°C.	9·13	5
7	1760	1011	23·14	11·33	—1·05°C.	11·33	5
8	1234	1013	20·94	10·10	—1·35°C.	10·08	5
9	887	1018	18·88	9·10	—1·66°C.	8·50	5

Table XIX.

Showing the scale of diet of certain Anglo-Indian and Eurasian Students.

Proximate Principles.	Beef or Mutton.	Potatoes.	Bread.	Mixed Vegetables.	Rice.	Dhall.	Jam.	Eggs.	Butter.	Ghee.	Sugar.	Milk.
Proteid . .	46·53	3·12	23·40	2·32	3·62	3·29	·06	1·62	...	...	...	3·60
Carbohydrate	...	74·32	184·32	6·04	44·41	8·11	2·63	...	...	...	56·72	5·21
Fats . .	18·88	·64	5·18	·38	·28	·26	...	1·64	12·12	12·12	...	3·25

Proteid = 87·56 grammes.
Carbohydrate = 376·53 "
Fats = 54·75 "
Salt = q. s.

From the 42 observations on the urine collected in Table XVIII we find the average elimination of nitrogen is 9·39 grms. daily, or the metabolism of 58·68 grms. of proteid from an intake up to a possible 87·56 grms. per day. This would apparently mean a very high percentage of proteid loss in the fæces

or a too liberal allowance of provisions, a large amount remaining uneaten. From enquiries we were given to understand that the rice and dhall often remained over but that the remaining portions are always consumed.

It must be remembered, however, that the students we are dealing with are all between the ages of 16 to 20 years—at the period of life when growth is very rapid—so that large quantities of nitrogen are being retained for the building up of the proteid-containing tissues ; this amount of nitrogen will therefore not appear in the urine at all, and any calculation of the proteid-interchange based on the excretion of the total nitrogen would therefore be too low.

From a personal experience extending over five years we can confidently assert that these students grow and develop very rapidly and, before their course at College is over, they have grown into strong, healthy men. As evidence that this is the case we have the fact that the College football, hockey, and cricket teams can do more than hold their own against the various clubs in Calcutta. It may be accepted that the diet sanctioned is therefore sufficient to cover all the physiological requirements of these students.

This opinion is borne out by weighment and measurement.

The average weight on entrance—age about 16 years—on all the observations we have been able to obtain is 115 lbs., and by the end of the third year has risen to an average of 133 lbs. or an increase in three years of over 18 lbs. in weight. The chest measurement over the same period shows a gain of up to an inch on the average. These figures are markedly different from what was found true for Bengali students.

By taking the average weight of these Anglo-Indian students we can estimate the proteid metabolism per kilo. of body-weight. It must be between the figures $\frac{58 \cdot 68}{57}$ and $\frac{87 \cdot 56}{57}$. The numerator of the former fraction is the amount of proteid metabolism calculated from the total nitrogenous elimination of the urine, the numerator of the latter is the gross proteid intake ; the denominator in both instances is the average body-weight in kilos. As it is evident from the above figures that rapid growth and muscular development are taking place, so that there is a large retention of proteid, the quantity $\frac{58 \cdot 68}{57}$ is too low ; further, as only about 85 per cent. of the proteid of a diet of the above type is absorbable it follows that the figure $\frac{87 \cdot 56}{57}$ is too high. We shall not be much in error, however, if we accept the latter amount, deducting 15 per cent. for non-absorbable proteid and taking into account the loss of proteid in the uneaten portions of rice and dhall ; this would bring the average proteid metabolism very close to 70 grammes daily, or expressed in terms of nitrogen would mean the metabolism of 11·2 grms. of nitrogen per day. The nitrogenous metabolism per kilo. of body-weight is therefore $\frac{11 \cdot 2}{57} = 0 \cdot 196$ grm.

Reference to Table XVI will show that this is a very much larger proteid metabolism than found in any of the different classes of Bengalis investigated, the prisoner of the Bengal Jails being the only case approaching it in quantity.

The influence of diet we consider is abundantly obvious in a comparison of these Anglo-Indian and Eurasian boys and the 568 Bengali students already analysed. The two classes enter College about the same age, live in the same climate and under very similar conditions; further, as we have pointed out, there is no racial reason why the Bengali should not grow out to be every bit as well developed as the other class; but the results at the end of their College career are very different. The Anglo-Indian and Eurasian boys develop into strong, healthy men quite up to the average of European standards, while the Bengali students almost remain stationary as regards development—the increase in weight and chest-girth being at a minimum, while the increase in height is very marked.

In any suggestions for an appreciable decrease in the proteid of the daily diet results such as these should surely serve as a warning. Is it not better to be guided by the practical effects of diet observed than follow out to its logical conclusion any theoretical deduction however plausible? The fact that nitrogenous equilibrium can be established on one-third of the quantity of proteid present in Voit's standard is no argument, in the face of the evidence obtained from this study of the metabolism of the Bengali, for straining every effort towards the establishment of a possible physiological economy.

(*b*) The physical development of Anglo-Indian and Eurasian students on a fixed and known diet.

The College from which we obtained our information regarding the 568 Bengali students was also able to provide us with observations under the same headings on 126 Anglo-Indian and Eurasian students. Again, the medical officer of the College kindly furnished us with the scale of diet sanctioned for these students. We have thus got the two classes—568 Bengalis and 126 Anglo-Indian and Eurasian—each on a known diet, living under exactly similar conditions as to climate, surroundings and work. A comparison of the physical development of these two classes should give us an interesting view of the effects of different degrees of nutrition.

The effects of a low proteid intake on the physical development of Bengali students will be found under Heading V of this section. Let us examine in the same way what the results are in the case of these Anglo-Indian and Eurasian students.

From the records we find—

(1) The average body-weight over the whole series is for first year 116 lbs., second year 123 lbs., third year 130 lbs. and fourth year 135 lbs.

That is, compared with a maximum increase in body-weight of 2 lbs. in the case of the Bengali students, we find an increase of 14 lbs. in Anglo-Indian and Eurasian students over a similar period.

(2) In a comparison of weight on entrance and weight in the third year only 2 per cent. show a diminution compared with 42·8 per cent. in the Bengali; practically 100 per cent. gained weight continuously during the three years—a marked contrast to the 15·3 per cent. of Bengalis who gained weight continuously.

(3) Less than 4 per cent. show a diminution in body-weight in the second year of attendance while 55·8 per cent. of the Bengali students lose weight during this period.

(4) In the Bengali the chest measurement does not alter, while the following are the averages for Anglo-Indian and Eurasian students, first year 33⅓ in. ; second year 34 in. ; third year 34¾ in., a very great increase during the three years for which figures are available.

(5) Growth in height is even more marked than in the Bengali students; practically everyone gaining considerably in height.

The diet on which these splendid results were obtained is shown on Table XX.

Table XX.

Proximate Principles.	Bread.	Butter.	Sugar.	Milk.	Ghee.	Dhall.	Oat-meal.	Condensed milk.	Rice.	Vegetables.	Beef.	Chicken curry.	Eggs.	Total constituents.
Proteid .	23·86	...	...	·90	...	12·18	1·58	3·25	12·70	2·02	30·35	5·31	3·82	94·97
Carbohydrate	153·42	...	76·57	...	...	34·04	17·91	2·13	152·05	34·88	...	...	...	467·00
Fat . .	1·56	22·56	...	·84	19·20	1·12	1·06	1·09	1·19	·27	3·10	·98	3·24	56·20

This is a very liberal diet compared with those analysed hitherto and is even a more liberal allowance than sanctioned in the case of the other Anglo-Indian and Eurasian students.

We need not go into all the details but from a similar calculation to that above we find that it affords a *minimum* metabolism of 0·203 grm. nitrogen per kilo. of body-weight, compared with the metabolism of 0·148 grm. nitrogen per kilo. of body-weight of the Bengali students of the same College. It is unnecessary to labour the comparison of the resulting condition of these two classes, the facts of the physical development gleaned from the medical officer's records speak with no uncertain voice and force on us the lesson taught by the other lines of

investigation and by the general tendency of the evidence we have been able to bring forward. It will be sufficient to put these facts in a concise form ; this we have attempted to do in Table XXI.

Table XXI.

Class investigated.	No.	Nitrogen per kilo.	Duration.	Physical Development.			
				First year.	Second year.	Third year.	Fourth year.
I. Bengali Medical Students.	44	0·116	life	...	Average 3445	...	...
II. Other Bengali Students.	568	0·148	4 years	3920	3920	3993	...
III. Bengali Prisoners .	4	0·185	variable	...	Average 4125	...	...
IV. Anglo-Indian and Eurasian Students	42	0·196	4 years	3795	4221	4588	...
V. Other Anglo-Indian and Eurasian Students.	126	0·203	4 years	3866	4172	4517	4825

Physical development is taken as being represented by the figures obtained from the multiplication of the weight in lbs. by the chest-girth in inches.

The interpretation of this table is obvious and need not detain us. Taken in connection with Table XV we get a very fair idea of the results attained by Chittenden and of those attained by ourselves in Bengalis and Anglo-Indians. We consider that the figures set forth in these tables prove conclusively that, with a diet poor in nitrogen, individuals are produced who are deficient in muscle, poorly supplied with blood and who exhibit defective development. With a liberal scale of proteid intake results the opposite of these are the rule. It would further appear from the results of computation of physical development—Table XXI—that general body-growth increases *pari passu* with the nitrogenous metabolism per kilo. of body-weight. Exactly where the line is to be drawn regarding the amount of proteid necessary in an ideal diet we are unable to say ; but we hold that the above figures would certainly seem to show that increases in bodily vigour and development take place up to a nitrogen metabolism of 0·203 grm. per kilo. of body-weight, or an interchange corresponding to nearly 80 grammes of absorbable proteid in the daily intake of food.

In connection with the growth and general physical development of the different classes of students whose metabolism and nutrition we have investigated, the following quotations from the discussion of anthropometrics in schools at the recent meeting of the British Association are of importance.

Dr. Shrusball—"Comparing the stature and height in schools of different classes it was found that at an age of 12 the children in the better schools were as large as children of 13 in the poorer schools; but there was less deterioration in the case of girls." (*Times* Report.) Sir Victor Horsley—"Some astonishing instances of results of school measurements were given. At Marlborough for twenty years boys have been annually measured and from a comparison of the figures it appears that the 1906 boys of 14 years old are about 5 lbs. heavier and nearly 1½ inch taller than the 1886 boys. The sixteen-year old boys of the present date keep up in proportion, being ¾ inch taller and 8 lbs. heavier. The meeting was amused by the evidence of a hatter who provides no fewer than six schools with hats. He was quoted as vouching for the scientific fact that a hat of 21½ inches used to be a rarity, but that now 22½ inches is continuously asked for." (*Empire* Report.)

VII.—Physical Endurance and other evidence.

(1) *Physical Endurance.*—In order to obtain a comparison between the vegetable-eating Bengali and the more meat-eating European labourers with regard to their power of performing work we have collected a certain amount of evidence.

It is exceedingly difficult to obtain anything like fair comparative tests, but anyone who has seen the ordinary Bengali coolie at work will not require much statistical evidence to convince him of the marked superiority of the European. We shall give, however, a summary of a few of the more pertinent points of evidence which will speak for themselves.

(*a*) The ordinary shovel or spade used by the European workman requires two Bengalis to work it—one makes use of it in the same manner as the European, the other by means of a rope tied above the iron part assists in lifting the spade-full or shovel-full of material.

(*b*) Some years ago the competition of "brown" labour was one of the bugbears of trade unionism owing to the institution of crude comparisons between the wages payable and the hours worked in India and England respectively. An expert, who has recently written on this subject, demonstrates that five or six times as many hands are needed in Indian spinning mills, and three times as many in weaving sheds, to produce the same result as in England.

The following table, modified from the recent report on factory labour in India, brings out very clearly and forcibly the relative productive capacity of the English and Indian worker:—

	England.	India.
Operatives per 1,000 spindles	4·2	28
Operatives per 1,000 looms	43	125
Annual outturn of yarn per operative . . .	7,736 lbs.	4,000 lbs.

	England.	India.
Weekly outturn of cloth per operative	767 yds.	240 yds.
Average approximate counts	40 *s.*	20 *s.*
Working hours per week	55½	80
Working hours per year	2,775	4,120
Monthly wages per spinning operative	Rs. 70	Rs.13
Monthly wages per weaving operative	Rs. 72	Rs.15

Neither wages alone nor hours alone can form a basis for comparing British and Indian labour costs. Indian labour is lacking in continuous application, punctuality, energy and regularity. Men have often to be employed in India for work that women will do in England. The Indian workers have little skill or education and consequently they make much waste ; their sense of discipline is imperfect ; their attendance irregular ; and they take long intervals for rest, smoking, etc. (Commercial Supplement of the *Times.*)

(*c*) In the coal mines of Europe and Bengal we have perhaps the best comparative test of the capabilities of the different classes of workmen. It must be remembered, however, that in the United Kingdom coal is mined at ten times the depth of the average depth of mines in Bengal; the great majority of Bengal mines being worked by inclines of only a few hundred feet in depth.

The relation between the number of hands employed and the output of the collieries varies considerably in different districts, being highest in those where the coal is moderately thick, soft, easily cut and with a good roof, and least in faulted and disturbed seams and those with a bad roof where the accessory operations of timbering and driving stone drifts requires the employment of a large number of the working staff on non-productive work, *i. e.*, other than cutting coal.

The following figures give the relative force employed above and below ground in two large steam collieries in South Wales each producing about 500 tons per day :—

Colliers cutting coal	225	200
Other underground hands	229	174
Surface hands	43	36
	497	410

showing in the one case an average of one ton, in the other about 1¼ tons per head per day.[1]

The annual output per man on the total force employed in the United Kingdom is about 300 tons.

(1) Encyclopædia Britannica.

For the last year for which statistics are available—1904—the output per man per annum was 287 tons in England; in America, where mining is simpler, it was 589 tons and in Germany 243 tons.

Compare these amounts with the following figures.

STATEMENT SHOWING THE PRODUCTION OF COAL IN INDIA FROM THE YEAR 1896 TO 1906.[1]

	Quantity produced.	Number of persons employed.
1897	4,066,294	59,859
1898	4,608,196	62,974
1899	5,093,260	74,450
1900	6,118,692	89,284
1901	6,635,727	95,318
1902	7,424,402	98,312
1903	7,438,386	88,530
1904	8,216,706	92,740
1905	8,417,739	89,995
1906	9,783,288	99,138

On the whole production for the last ten years the average output per head per annum is under 80 tons or about 27 per cent. of the average of a European miner.

So far as conditions of work go both European and Bengali miner is paid on the output; on the other hand the European labours under very great disadvantages compared with the Bengali. As we have seen, he works at a much greater depth and usually from a very thin seam of coal, often being quite unable to stand upright to his work; the Bengali, on the other hand, cuts his coal from great thick seams usually; in fact, his work is more like quarrying than mining proper.

The output from lignite quarry mines in Europe is about 600 tons per man per annum.

The physical conditions are altogether in favour of the Bengali and the result is an outturn barely 27 per cent. of that of the European.

(1) Capital; 1907.

Many other instances of the inferior capabilities of the native workman might be given, but we have said enough to support our contention that, physical development depending largely on diet and environment, the vegetable-eating Bengali on a diet poor in nitrogen is incapable of performing the same amount of work—physiologically, of liberating the same amount of energy per unit time—as the meat-eating European workman. We do not mean to imply by this statement that the energy of muscular contraction comes from the nitrogen of the food, but we do assert that the deficient nitrogenous intake of the Bengali does not permit of the development of the muscular tissue necessary for the performance of the same amount of work.

(2) *Life Insurance.*

The lowest rate for insurance of Indian lives is 33 per cent. higher than for Europeans in Europe.

From information acquired from several insurance offices we have obtained evidence pointing to the fact that, from an insurance point of view, the life of the Bengali is very inferior to the European. The manager of one of the largest offices dealing with native lives said that, if it were not for the fact that the policies on Bengalis were, in a large percentage of cases, closed after a few years' premia had been paid, the company would be compelled to stop whole-life insurances on natives.

The company, as it is, rates all Bengali lives five years, *i.e.*, a Bengali insuring at age 30 next birthday pays the same rate as a European aged 35 next birthday.

One large office in Calcutta which does an exceedingly lucrative business in native insurances will only accept the policies of well-educated Bengalis of the higher castes, and even then only up to an age of 35 to 38 years; this company will not accept a whole-life policy at all and the medical examination is very strict—a slight excess of measurement round the waist being quite sufficient to cause rejection.

Another method by which insurance companies safeguard themselves is to accept lives insured only for a certain number of years—10, 15 or 20—the fewer the years and, therefore, the higher the premia the more welcome the policy.

Under conditions such as these and others the specially selected native life is superior to the European in India. There is no such thing as a general acceptance of policies on the life of anyone who can pass a physical examination as holds in Europe and America. Another important point throwing light on the expectation of life in the Bengali is that an endowment policy is very rarely granted maturing above the ages of from 50 to 55 years. The explanation given of this is that policies maturing beyond these ages were found not to pay, death occurring before the companies had obtained sufficient in premia to cover the amount of the policy.

(3) *The power of resistance to disease.*

Chittenden states " the smallest amount of food that will serve to maintain bodily and mental vigour, keep up bodily strength and preserve the normal powers of resistance to disease, is an ideal diet. Any excess over and above what is really needed for these purposes imposes just so much of an unnecessary strain upon the organism. It imposes on the excretory organs the needless labour of removing waste products which could well be dispensed with—the elimination of these bodies through the kidneys places upon these organs an unnecessary burden which is liable to endanger their integrity and possibly result in serious damage". The amount of proteid food required by adults, he says, is fully met by a daily metabolism equal to an exchange of 0·12 grm. nitrogen per kilo. of body-weight.

While agreeing with the view expressed above to a large extent, we consider the whole importance rests on the amount of food that " preserves the normal powers of resistance to disease ". We have found that the Bengali exists on a proteid metabolism very close in amount to that stated by Chittenden to be sufficient ; let us, therefore, examine the evidence of his resisting power to disease.

Chittenden attaches great importance to the strain thrown on the excretory organs from an excess of proteid over and above what he considers necessary ; we are forced to the conclusion, however, that there is another and a very important side of the question to be considered, *viz.*, the danger of malnutrition of the renal epithelium from a lowered or impoverished condition of the blood accompanying a low proteid intake. We have searched in vain for any reference to this probable source of danger in Chittenden's publications and in the works of other authors. That it is a point worthy of investigation and not to be overlooked we shall endeavour to show.

It is well known that stoppage of the flow of blood through the renal vessel —as by ligature of the renal artery or vein or temporary stoppage by pressure on the abdominal aorta—even for a very short time will cause extensive changes in the renal epithelium and, if at all prolonged, will mean total loss of its vitality.

With a transitory stoppage or even with a sluggish flow from back pressure albuminuria results ; that is, the epithelial cells are unable to prevent the albumen of the plasma from filtering through. It may, therefore, be accepted that the delicate cells lining the renal tubules require for the up-keep of their normal vitality a certain minimum of a constant supply of nutritive materials brought by the plasma of the blood; any diminution in the supply below this minimum will inevitably lead to loss of vitality and loss of function. It will not matter so far as the malnutrition of the renal cells is concerned whether this is brought about by a diminution in the velocity of the flow of blood or by a diminution in the percentage of nutritive material present in the blood; in both instances the

necessary nutritive exchanges are deficient and the cells suffer. We can quite easily imagine a condition of the blood it which this malnutrition of the renal epithelium obtains with even a full free flow of blood through its vessels. Such is met with in the extreme forms of anæmia due to ankylostomiasis so prevalent in this province. As has been shown already [1] a similar condition of "renal impermeability" to chlorides, as seen in ordinary nephritis, was found to be present in ankylostomiasis, and the recent report of the Porto Rico Commission would prove conclusively that albuminuria is a very common feature of this infection. Further, the Commission emphasizes the fact that the accompanying albuminuria with casts should be regarded as the evidence of a degenerative process in the kidney, not as an inflammation or, more specifically, nephritis. We have, therefore, in the anæmia of ankylostomiasis a degeneration of the epithelial cells and impairment of function due to an impoverished condition of the blood.

That the total solids and nutritive materials of the blood are very deficient in ankylostomiasis we have satisfactory analyses to prove. In certain cases we have found the dry residue decreased well over 50 per cent.

Exact information is wanting regarding the degree of impoverishment of the blood plasma the kidney epithelial cells are capable of withstanding before degenerative changes begin to occur. We do know, however, that on a liberal proteid intake the blood contains about 20 per cent. of proteid and, on a diet containing 50 per cent. less proteid, it can and has been proved that there is a considerable fall in the total solids and in the floating proteids of the plasma—the source from which these epithelial cells derive their nutrition.

With this knowledge at our disposal the question arises : are we justified in lowering the nitrogenous constituents of the plasma by lessening the amount of proteid in the daily food, even though with this lessened proteid intake certain theoretical dangers may be obviated ? We use the word theoretical advisedly, as it has not been proved that the healthy individual is injured by a proteid diet of the ordinary standards. Von Noorden asks the pertinent question in this connection, "are carnivora less healthy than herbivora because they consume a larger quantity of flesh ?"

Instead of the theoretical dangers that are to be avoided by a greatly diminished proteid intake, we consider that very real dangers may arise from this very diminution, *viz.*, degenerative and fatty changes from lack of proper nutrition in the delicate glandular and excretory cells of the body.

In order to obtain the available evidence of the low proteid diet of the Bengali on the incidence of renal disease compared with the more nitrogenous food of the European we examined the records of the medical cases treated in

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[1] M'Cay ; *Lancet*, 1st June 1907.

the Medical College Hospital, Calcutta; St. Thomas' and St. Bartholomew's, London, with the following result :—

Cases discharged or dead from medical wards of the Medical College Hospital, Calcutta, during 22 months from June 1905.	Total kidney cases discharged or dead during the same period.	Percentage of kidney cases to total treated.
Total 3,622	120	3·05
Europeans 1,320	26	2·0
Natives 2,282	94	4·1
St. Thomas' Hospital (1904) Total 2,589	136	5·3
St. Bartholemew's Hospital (1904) Total 2,512	95	3·7

So many other factors besides diet would require to be taken into consideration that too much importance cannot be claimed for these figures; on the other hand, in a country where scarlet fever is unknown the incidence of renal disease is amazing and would not appear to support Chittenden's contention that with a low proteid diet kidney function is less likely to become impaired. So far as the evidence goes, it would tend to show that, even with the exceedingly low nitrogenous intake of the general population of Bengal, kidney disease is more common among natives than among Europeans. This is a statement that we think all physicians of a large general hospital will subscribe to; personally we have found kidney troubles exceedingly common in the outdoor dispensary of the Medical College Hospital.

With regard to the power of resistance to other pathological conditions, as, for instance, septic infection, reaction to inflammatory processes, recovery from shock and similar processes, information is almost entirely wanting. We consider that it would be generally admitted that natives stand acute infections such as pneumonia, plague, cholera, etc., badly; on the other hand they would appear to take chloroform well. It is exceedingly difficult to make any definite statements, but there is a large field for research and accurate observation on the differences in temperament and reactions in disease exhibited by the European and native Indian. Why, for instance, is scarlet fever unknown in India? Why do the nervous manfestations of syphilis appear so early after infection? Why do they so commonly take the form of syphilitic paraplegia and so rarely that of locomotor ataxia? By what inherent power can the native of India, having once made up his mind that death is approaching, turn his face to the wall and pass to the land of the Hereafter?

The last subject connected with the power of resistance to disease on which we wish to speak is the dietetic form of glycosuria. So far we have avoided or

passed over in a sentence the carbohydrates and fats of the several diets. This was not because they are of little importance, but for the simple reason that in all the diets we have examined these elements were sufficient in amount and, as far as could be seen, called for little comment.

Great importance has been attached by Chittenden to the evil effects of a diet too rich in nitrogen and with him our observations on Bengalis and others would lead us to go a certain length; but, from the arguments advanced in the previous pages, we would draw the line much before a decrease of 50 per cent. in the proteid of Voit's diet had been reached.

Even if one grants that in the normal decomposition of proteids toxic bodies are formed which, while in the body or during their excretion, may act injuriously, it is by no means certain that decomposition products also toxic in nature are not formed from the carbohydrate and fat of the diet. In connection with this, the extreme prevalence of glycosuria amongst the upper middle classes of Bengalis would prove conclusively that the danger of an excess of carbohydrate intake is even a more real and present one than that of proteid excess.

Glycosuria, either with or without albuminuria, is one of the commonest diseases met with in the class above-mentioned and is a very frequent cause of death. After the age from 45 to 50 years a very large percentage of these individuals suffer from one or other of these conditions. It usually begins as a simple dietetic form due to the large quantities of starchy food and sweetmeats consumed, but, after a longer or shorter period, develops into true diabetes, impairment of kidney function and accompanied with the usual complications of both the primary and secondary diseases. We have already stated the views we hold regarding the danger of damage to the renal epithelium from a low nutritive power of the plasma; in the form of glycosuria we speak of it would appear probable that the plasma is quite unable to prevent epithelial degeneration and albuminuria. In a series of 325 cases of glycosuria Dr. Bose [1] found that 65 per cent showed evidence of kidney damage.

Whether the damage to the kidney is due entirely to the continual elimination of sugar and changes in the composition of the blood from the formation of decomposition products of faulty carbohydrate metabolism such as β-oxybutyric acid, aceto-acetic acid and acetone, or whether the low nutritive condition of the plasma does not form an important factor in its causation, we are not in a position to say.

It is a remarkable fact, however, that diabetes mellitus in Europeans is not accompanied in any very high percentage of cases by organic changes in the kidney—at least, not in the earlier stages of the disease; whereas in the Bengali, albuminuria, even at the beginning of dietetic glycosuria, is fairly common.

(1) C. L. Bose: Some observations on Diabetes, Cal. Med. Journal, September 1907.

We are greatly inclined to think that the explanation of these differences rests largely with the nutritive power of the plasma in the two classes of people; the poor nitrogen content of the plasma in the Bengali starving the renal cells and causing them to lose their physiological property of preventing a filtration of the serum albumen of the blood into the tubules.

The disturbances of the organism we more particularly wish to emphasize in dietetic glycosuria are the lowering of the resisting power of the tissues to microbic invasion and lessening of their vitality. The common complications of diabetes, pneumonia, tuberculosis, carbuncle, spreading gangrene, etc., all speak of lowered vitality and increased susceptibility. Before complications such as these appear there must be a time when, although in a lowered state of vitality, the tissues are just able to resist infection. It is generally held that the percentage of sugar in the blood should reach from 0·2 to 0·3 before glycosuria occurs, but long before this ratio is attained degenerative changes, the result of lowered vitality, have begun.

It would, therefore, appear that the large carbohydrate intake rendered necessary by a diet poor in nitrogen, and of course much more so the great quantities of sugar consumed by the Bengali, is even more likely to lead to injury and damage to the delicate tissues of glandular and other organs and to a diminution in the resisting power of the system than any excessive nitrogenous intake.

No. 34

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BY

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ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA, SIMLA

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1908

Price an